A
PHILOSOPHICAL ESSAY
CONCERNING
LIGHT.

VOL. I.

G.R. III
BRITISH MUSEUM

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A PHILOSOPHICAL ESSAY CONCERNING LIGHT.

By BRYAN HIGGINS, M. D.

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Vaga enim Experientia, et ſe tantum ſequens, mera palpatio eſt; et homines potius ſtupefacit quam informat.

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VOL. I.

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G.B. III.
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To the MEMBERS

Of the MEETINGS

LATETY HELD

FOR THE PURPOSE OF IMPROVING

NATURAL KNOWLEDGE,

This ESSAY

COMMENCED AT THEIR INSTANCE,

IS GRATEFULLY INSCRIBED,

BY THEIR MUCH OBLIGED,

AND MOST OBEDIENT SERVANT,

B. HIGGINS.

G.R. III
BRITISH MUSEUM

THE

PREFACE.

A JUST SENSE of the utility of the Chemical Art, towards promoting Natural Knowledge, prompted me at a very early period of my life, to employ myſelf privately in the Practice of Chemiſtry, and to attend with the utmoſt diligence to the phenomena which occur in the proceſſes of Chemiſts and divers other artiſts.

Obſervations thus made, and ſtrongly impreſſed on the memory, could not, in the courſe of years, fail to ſuggeſt general notions, and many new experiments: But whilſt I was engaged in theſe, and my views were extending, the expences became too great to be continued with prudence.

It was at this juncture that I reſolved to open a ſchool of practical Chemiſtry, wherein the pupils might have uncommon advantages, at the ſame time that my apparatus might be enlarged, and my experiments well conducted, at a common expence.

My firſt courſe, which commenced on the 5th of July, 1774, being patronized and attended by ſeveral learned gentlemen, I endeavoured to render it intereſting to them, by introducing the ſeveral ſubjects and doctrines afterwards mentioned in my ſyllabus publiſhed laſt winter. In each of two ſucceeding courſes, as well as in this, I had the good fortune to addreſs my lectures to the moſt indulgent and liberal audience; by whom my endeavours were cheriſhed, and I was encouraged to publiſh the following propoſals.

Doctor HIGGINS, *of Greek-ſtreet, Soho, encouraged by the Literary* NOBLEMEN *and* GENTLEMEN, *who have ſubſcribed to his* COURSES *of* PHILOSOPHIC *and* PRACTICAL CHEMISTRY, *addreſſes the following* PROPOSALS *to the Patrons of Natural Philoſophy and uſeful Arts.*

PROP. I.

THAT fifty philoſophic and literary gentlemen do concur in promoting experimental enquiries into the elements of matter and laws of Nature, and ſuch other ſubjects as are moſt important in Natural Philoſophy, Chemiſtry, and Arts:

II.

That until better meaſures can be deviſed and agreed on, the plan, offered in theſe propoſals, be adopted :

III.

That as the Elaboratory of Dr. HIGGINS is already provided with a conſiderable apparatus, and ſeveral neceſſary accommodations for the abovementioned purpoſes ; and as he has manifeſted a diſpoſition and attention which recommend him on this occaſion, his Elaboratory ſhall be the place wherein theſe enquiries ſhall be made, and he ſhall conduct the experiments :

IV.

That a ſubſcription be immediately opened by him for the purpoſes expreſſed in the foregoing and the ſubſequent propoſals : That each ſubſcriber do contribute ten guineas : That the gentlemen who are deſirous to ſubſcribe do give the earlieſt notice thereof to him ; and that the ſubſcription be cloſed when fifty gentlemen ſhall have ſubſcribed :

V.

That the firſt general meeting of the ſubſcribers be on *Monday* the 13th of *November*, 1775, at ſeven o'clock in the afternoon, in the elaboratory abovementioned; and that they be, every other day, for three months thereafter, at an hour to be appointed by the ſubſcribers at the firſt meeting:

VI.

That previous to theſe meetings, he do appropriate an hour every day, from ten to eleven o'clock in the forenoon, to hear the ſentiments and receive the inſtructions of the ſubſcribers----- the month of *July* only excepted:

VII.

That he ſhall preciſely at the hours to be appointed, open each of theſe meetings with a diſcourſe in the didactic form: That in theſe diſcourſes he ſhall introduce the natural phenomena, the illuſtrative obſervations and experiments of philoſophers, chemiſts and artiſts; and particularly his notions and experiments concerning the primary elements and the properties of matter:

That by bringing into one view what hath been hitherto diſcovered, together with a conſiderable number of ſuch new and concluſive experiments on theſe ſubjects, as he hath deviſed, and as ſhall be maturely deviſed by the ſubſcribers, he ſhall endeavour to improve the former, or eſtabliſh better doctrines:

VIII.

That every thing to be advanced by him on theſe occaſions, ſhall be ſupported by obſervations and experiments to be made in a conſpicuous manner before the ſubſcribers, or by producing the apparatus and reſult of ſuch experiments as require much time, and muſt neceſſarily be made during the intervals of the meetings:

IX.

That each introductory diſcourſe ſhall not exceed half an hour, unleſs protracted by very intereſting experiments; and that afterwards the time be employed by the ſubſcribers in communicating, objecting, propoſing or deviſing whatever may be thought conducive to the purpoſes already expreſſed:

X.

That the ſubſcribers be at all times admitted to ſee and direct the operations and experiments:

XI.

That minutes be taken of the proceedings, recording all that ſhall be meritoriouſly ſuggeſted or done by each ſubſcriber; and that theſe minutes be the property of the ſubſcribers:

XII.

That aſſiſted and adviſed by the learned gentlemen who have already ſubſcribed, and thoſe who will pleaſe to ſubſcribe in due time, he ſhall exert himſelf during the ſummer and autumn previous to the propoſed meetings, in preparing and arranging the matter of the intended introductory diſcourſes; in forming a ſyllabus for the uſe of the ſubſcribers; in deviſing inſtruments and experiments, and making an addition to his preſent apparatus, ſuitable to the occaſion and the above mentioned liberal ſubſcription:

FINALLY.

That he ſhall be accountable for the ſubſcribed ſums, in caſe he ſhould be prevented, by ſickneſs, or otherwiſe, from performing his part in this undertaking.

A conſiderable number of the moſt reſpectable gentlemen acceeded to theſe propoſals; my original intention was accompliſhed; and they added this further advantage :—Their obſervations and communications, during the meetings greatly contributed to the advances then made, and to my improvement, in natural knowledge.

In compliance with the wiſhes of theſe gentlemen, I engaged to publiſh, during the ſummer receſs, ſome parts of the diſcourſes and experiments made in their preſence : And thoſe which related to *Phlogiſton*, and the *Elaſtic-fluids* were the parts which I intended firſt to publiſh ; becauſe they comprehended the greateſt number of intereſting experiments ; and I was thought to underſtand them, better than any other ſubjects of natural philoſophy : But on the firſt attempt, I found it impoſſible to write of them, in any manner that could ſatisfy even my own judgement ; without aſſuming, as *data*, a great number of propoſitions totally repugnant to the received Theories of Light and Fire.

I therefore reſolved, notwithſtanding my incompetency for ſuch a taſk, and the ſhortneſs of time allotted for it, and my bad ſtate of health, to treat firſt of Light; which I conceive to be preſent, under one form or another, and to be active, in all natural operations, and in every experiment; and whoſe agency muſt be aſcertained, in ſome meaſure, before we can explain the phenomena which are moſt noticed by our modern Philoſophers.

In four months I proceeded a conſiderable length in this undertaking; but then having only one month of the time preſcribed, remaining for the reviſal and printing of the papers I had haſtily thrown together; I thought it adviſeable, to commit to the preſs, no more than appears in this firſt volume, which is little more than an introduction; and to reſerve the more important parts of the intended work, for a future and more mature publication, which ſhall be made to form a ſecond volume in the courſe of a few months.

As it is my purpoſe rather to promote enquiry, than to give a ſpecious appearance to any particular ſeries of doctrines, I intentionally avoid ſyſtematic order; and handle the ſeveral ſubjects of the enſuing pages in the manner which I think moſt likely to engage philoſphic minds in the important inveſtigation of Light and Fire.

It may be remarked that, in this firſt volume, I frequently quote Sir

Iſaac Newton, but ſcarcely mention the name of any other writer. Sir *Iſaac Newton*'s acknowledged excellence, and the reſpect paid not only to his doctrines, but to others unjuſtly aſcribed to him, demand a particular attention to what he has written concerning Light and the ſubjects related thereto: I therefore am obliged to tranſcribe ſeveral paſſages of his works: but as the ſubjects which I introduce in ſubſervience to the Theory of Light, are numerous; and as it is totally inconſiſtent with the brevity intended, to quote all the other authors who excel in ſo many different departments of natural philoſophy; I chuſe rather to avoid ſuch quotations as much as is poſſible, than to betray an unjuſt partiality by naming only a few of the many writers to whom I profeſs myſelf greatly indebted. This choice however, only concerns the introductory part of this eſſay; for when I treat expreſly of Light, I ſhall pay due attention to the ſeveral writers on this ſubject.

As there are but a few copies remaining of the ſyllabus publiſhed laſt year, purſuant to the foregoing propoſals; and ſince this ſyllabus is likely to furniſh ſome hints which will facilitate the reading of the ſubſequent introduction, eſpecially to thoſe who are not thoroughly acquainted with the diſcoveries recently made by philoſophical chemiſts, I have ordered it to be reprinted in this place.

A Syllabus of Chemical and Philoſophical Enquiries, compoſed for the Uſe of the NOBLEMEN *and* GENTLEMEN *who have ſubſcribed to the Propoſals made for the Advancement of* NATURAL KNOWLEDGE.

INTRODUCTORY diſcourſe on matter in general, called groſs matter; on the varieties and diſtinctions of groſs matter; on the primary elements of matter.

Obſervations on the experiments and phenomena exhibited in the foregoing courſe of chemiſtry, and other experiments which demonſtrate the exiſtence of ſeven diſtinct elements of matter, *viz.*

Earth, Water, Acid, Alcali, Air, Phlogiſton, Light.

Experiments, obſervations, and arguments, ſhewing upon what grounds, fire, the etherial fluid of modern philoſophers, and the mercurial principle of the chymiſts, are to be rejected from the claſs of primary elements.

Experiments obſervations and arguments perſuading that each primary element conſiſts of atoms homogeneal; that theſe atoms are impenetrable, immutable in figure, and inconvertible.

Obſervations and experiments perſuading, that the atoms of each element are accurately or nearly globular; and that the ſpiral, ſpicular, and other figures aſcribed to theſe atoms, are fictious, unneceſſary, and are inconſiſtent with the uniformity and ſimplicity of nature, and repugnant to experience.

Practical applications of theſe doctrines; diagrams conſtructed in conſequence thereof, and obſervations on the uſes and importance of diagrams in the enſuing reſearches.

Obſervations illuſtrated by experiments of our ſenſe of the foregoing ſeven elements, ſeparately; of our ſenſe of the union of two or more of the foregoing elements. Experiments and obſervations ſhewing, that the poſſible and known unions of the foregoing elements, and that the poſſible and known proportions, in which the unions of the foregoing elements may take place, are more numerous than the bodies diſtinguiſhed by philoſophers or naturaliſts; perſuading, that all bodies are really compoſed of one or more of the foregoing elements; and that all bodies muſt be admitted to conſiſt of theſe only, until other elementary matter is found neceſſary for the explication of the natural phenomena, and is demonſtrated to exiſt.

A claſſical arrangement, on the table, of bodies compoſed of two or three primary elements; which bodies, in various chemical proceſſes, not being decompoſed, we call chemical elements, or the elements of the chemiſts.

A like claſſical arrangement of bodies compoſed of two chemical elements.

A like claſſical arrangement of bodies compoſed of many chemical elements.

Remarks on the foregoing bodies, with a view to inculcate ſuch general knowledge of them as will facilitate the future inveſtigation of the elements and properties of matter, &c.

Examination of the doctrines of authors, who admit various kinds of attraction, as ſo many diſtinct laws of nature; of others who aſcribe attraction and repulſion to the agency of an ethereal repellent fluid; and of others who attribute the attraction of bodies to the operation of an intermediate matter or cementing principle.

Review of experiments made in the preceeding courſe of practical chemiſtry, and obſervations authoriſing the propoſal of the following opinions, and the phrazes briefly expreſſing them, with a view to facilitate the enſuing inveſtigations.

Opinions.

1. That the homogeneal atoms of five elements, repel reciprocally.

2. That the homogeneal atoms of two elements attract reciprocally.

3. That the heterogeneous atoms of five elements attract reciprocally.

4. That the heterogeneous atoms of two elements repel reciprocally.

5. That the attraction ſubſiſting between elementary atoms, is more forcible in one direction or axis of each atom, than in

any other direction; and that there is a polarity in all matter whatever.

6. That there is but one cauſe of attraction operating with great force between the homogeneal or hetorogeneal atoms of certain elements; and with leſs force between thoſe of other elements, in gradations; but in all affected by diſtance and polarity.

7. That the attractions of bodies enumerated as diſtinct properties of matter or laws of nature, are nothing more than the ſums of the attractions of their elementary atoms; or theſe forces counteracted in a certain degree by the preſence of repellent atoms, or theſe forces exerted to the greateſt advantage in bodies whoſe primary attractions are ſtrongeſt, and whoſe atoms are alſo arranged in polar order.

8. That ſpecific gravity is not as the denſity of bodies, except when the bodies conſiſt of the ſame kind of matter; but that it is as the quality of the bodies, or the ſum of their elementary attractions: conſequently that light bodies are not neceſſarily more porous than the heavieſt.

Obſervations on the phenomena preſented in the practical courſe of chemiſtry, and authoriſing the following poſitions concerning fire: *viz.*

1. That fire pervades all known bodies.
2. That fire expands all known bodies.
3. That fire produces effects on bodies diametrically oppoſed to the power of attraction:—That it counteracts and in effect weakens, balances, or overpowers the force of attraction,
4. That poſitions concerning the univerſal effects of fire, but extending no further, and equally conſiſtent with nature and the doctrines of philoſophers, may be inſerted in any part of a ſyſtem of natural philoſophy, antecedent to the inveſtigation of the cauſe of theſe effects.

Of the Earthy Element, and Bodies conſiſting of this Matter chiefly.

The metalizable earths, the unmetalic earths, and compound earthy bodies arranged on the table.

Obſervations and experiments ſhewing, that near ſix hundred diſtinctions of earthly bodies, made by naturaliſts, altho' uſeful in arts, are to be rejected in chemical philoſophy, inaſmuch as theſe varieties are produced in many by the mode of aggregation only, and in others by heterogeneous admixture or combination.

Obſervations and experiments ſhewing the grounds on which we ought for a while to admit the following diſtinctions of earths, *viz.*

Seven earths capable of forming, with phlogiſton, ductile metals.

Seven earths, capable of forming, with phlogiſton, metals not ductile.

Seven earths, incapable of forming metal, in any known chemical proceſs.

Quer. Is there but one earthy element, which in various modes of aggregation, or in indiſſoluble combination with other elementary matter, forms twenty-one earthy bodies?

Quer. Are there three times ſeven, or ſeven times ſeven earthy elements?

The affirmative of the firſt queſtion urged by experiments obſervations and arguments.

The negative of the firſt queſtion urged by obſervations and arguments.

Probable conluſions.

New experiments with a view to decide on the foregoing queſtions.

Propoſitions concerning the method to be obſerved in the enſuing enquiries; and arguments perſuading that if we confine ourſelves to the conſideration of properties common to all earthy bodies, our future reaſoning will not be erroneous, whether there be, only one, or many earthy elements.

Illuſtrative diagrams, exhibiting the circumſtances in which we may, without inconvenience, uſe the word earthly element, for the future; and the circumſtances in which we may occaſionally attend to the chemical claſſes of earthy bodies, yet avoid contradiction or error.

Experiments and obſervations ſhewing that the earthy atoms attract the atoms of other elements; and arguments perſuading that theſe attractions are not to be further conſidered in this place, but reſerved until the other elements come under examination.

Experiments and obſervations ſhewing that the homogeneous atoms of earth attract each other.

Experimental eſtimation of the force of this attraction in fortuitous arrangment of the atoms, and of the force of this attraction in the polar arrangment of the atoms.

Experimental eſtimation of this attraction in the contact, compared with its force at given diſtances of the atoms.

Review of the phenomena exhibited in the practical courſe of chemiſtry, which authoriſe the anticipation of doctrines hereafter to be enforced by experiments, *viz.* The doctrine of the repulſion of the homogeneal atoms of all elements except earth and water; of the forcible attraction of earthy atoms to each other; of the force with which they attract other elements; of the quantity of earthy matter, and of the ſum of the attractions of earth to earth and other matter. Inductions that earth ought to gravitate more than any other known matter, and as it doth gravitate agreeable to the premiſes, that the gravitation of the earth is not to be conſidered as a law of nature, but as the ſum of the forces of the ſimple attractions of earth to earth and other matter.

The attractive power which cauſes the aggregation and gravitation of earth conſidered in oppoſition to the action of fire. General obſervations on fixity, expanſibility, fuſibility, fluidity volatility, evaporation. The fixity of earths deduced from the foregoing properties of this element; fixity being an effect of attraction.

The other properties of this element, and the concluſions further deducible from theſe already recited, are to be ſubjects of future conſideration.

Of the Element of Water.

Of diſtilled, rain, river, ſpring, and mineral waters, and and their impregnations.

The experiments of Boyle, Borrichius, Wallerius, Leidenfroſt, Margraaff, Eller, and Lavoiſier, conſidered, and the concluſive experiments repeated; together with new experiments proving water to be an elementary matter incapable of decompoſition; that the pretended converſation of water into earth is an erroneous notion, and that there is but one aqueous element.

Obſervations and experiments perſuading, that the pureſt known ſtate of the watery element, is that of ice, and that ice becomes fluid by the interpoſition of fire, or aerial, or acid, or other matter, demonſtrable in all fluid water, and expelled or drawn away in freezing.

Various phenomena of natural and artificial freezing exhibited and explained

Obſervations and experiments, ſhewing that the indeſtructible immutable atoms of water do attract each other: ſhewing fur, the rate of this attraction in contract of the atoms and at given diſtances between them: And ſhewing that this attraction is leſs forcible than the attraction of homogeneous earthy atoms: And that the atoms of water have polarity.

Obſervations and experiments proving that water and earth reciprocally attract each other.

Obſervations on capillary attractions, introſuſception, weting, &c.

Eſtimation of the attractive powers exerciſed between the atoms of water, and between water and earth and other matter, and of the relative quanties of theſe.

Inductions that the gravitation of water correſponds with the ſum of its primary attractions.

Experiments, ſhewing that the bodies of the greateſt ſpecific gravity, as gold, &c. when finely divided will float on water, or remain a long time ſuſpended in it wherever they are placed.

Theſe phenomena, and many others, particularly the phenomena of bubbles, drops and ſtreams of water, and of the formation of ſpars, ores, &c. explained; and reaſons aſſigned to ſhew why bodies are formed in water and works effected in the lapſe of time, which no art can extemporaneouſly accompliſh.

Reaſons why phenomena of water with inflammable and other bodies are not yet to be introduced.

Experiments demoſtrating the effects of fire on water in all the varieties induced by preſſure, whether by the altitude of the column, or by air, vapour, &c, and experiments relative to the balneum mariæ, balneum vaporis, Papin's digeſtor, water ſuſtaining red heat, evaporation, diſtillation, condenſation, ebullition in air and in vacuo, exploſions of water; and obſervations on the circumſtances in which this element is palpable or only viſible, or totally inviſible.

Explanations of theſe phenomena, according to the premiſed properties of water and the known effects of fire.

Of the Alkaline Element.

Chemical hiſtory of alkaline ſubſtances, in the order in which they ſtand on the table.

Experiments, ſhewing the inſufficiency of the vulgar teſts of alkaline ſubſtances; that alkali doth exiſt in all bodies from which it is by any means obtainable; that it is not the *creature of fire*, as many chemiſts imagine; that it is only extricated by fire, as other matters are from compound bodies. Inductions that fire ſevers bodies, but neither creates nor deſtroys matter.

Obſervations and experiments ſhewing that all the alkaline ſubſtances of the chemiſts, are compound bodies And that the cauſtic volatile alkali is that which is leaſt compounded.

Experiments ſhewing the alkaline matter uncompounded; and that this kind of matter, altho' never reckoned among the elements conſtitutes an element; and that all alkaline bodies conſiſt chiefly of this matter.

Obſervations and experiments, ſhewing that the atoms of the alkaline element repel each other; and ſhewing the rate of this repulſion at given diſtances between them, and that by reaſon of this repulſion varied with the diſtance, this element is an elaſtic, compreſſible, expanſible fluid.

Experiments ſhewing the repulſion of the atoms of this element, counterpoiſed by the attraction of other matter, and the formation of fluids of greater denſity or leſs volume, but yet inviſible: And next the repulſion of the atoms of the alkaline fluid overpowered by the attraction of other matter to theſe atoms, which are thus approximated ſufficiently to form a palpable fluid: And laſtly, the repulſion of the atoms of the alkaline fluid ſo much overpowered by the attraction of other interpoſed matter, that ſolid ponderous maſſes are formed therewith.

The cementing principle, *alkaline air*, and other conceits of the like nature, conſidered.

The true cauſes of ebullition, intumeſcence, effervеſcence, and of the incoercible vapours of the chemiſts, conſidered; and practical advantages reſulting from this knowledge, experimentally demonſtrated.

Experiments and calculations aſcertaining the diſtance to which the repulſion between the atoms of alkali can be extended, with a force equal to the whole preſſure of the atmoſphere: The force of this repulſion alſo conſidered at ſmaller and greater diſtances.

Probable ſuggeſtions that repulſion and attraction, which are forcible in contact, leſs forcible but yet meaſurable at various diſtances of the atoms, do univerſally extend to diſtances indefinite.

Inductions explaining the conditions in which matter is inviſible, viſible, fluid, ſolid, compreſſible like air, or incompreſſible; and experiments ſhewing, that alkali, like other matter, reduced to a ſtate in which it eludes vulgar obſervation, and in which it hath been ſuppoſed to be loſt or commuted, is nevertheleſs identical, incommutable, indeſtructible; and that the attractive and repulſive powers of alkaline matter ſuffer no ſuſpenſions, fits, or interruptions, and never are commuted in any circumſtance or diſtance, but only balance or overpower one the other, and thus occaſionally ſeem to be weakened or deſtroyed.

General obſervations of the elaſticity of fluids and of ſolid bodies.

Experiments ſhewing that repulſion is the cauſe of the former elaſticity and attraction the cauſe of the latter.

Inductions concerning fluidity, ſoftneſs, hardneſs, plaſticity, ductility, brittleneſs, applied to earth, water, alkali, and compounds of them, and equally applicable to other elements and compounds.

Experiments to determine whether the alkaline element conveys ſound, which it is preſumed it will do.

Obſervations and experiments ſhewing the polarity of the alkaline atoms, and the difference of the aggregation's formed by fortuitous arrangment, from thoſe formed by polar arrangement of theſe atoms in combination.

Saturation conſidered in the manner of the ſchools.

The true cauſe of ſaturation inveſtigated.

Experiments ſhewing that no element doth ſaturate, nor can ſaturate the like element; that no element, whoſe atoms attract each other, can ſaturate any other element whoſe atoms attract each other; that a repellent element doth ſaturate non-repellent elements, and *vice verſa*; that repellent elements do ſaturate reciprocally; and that attractive and repulſive powers operating adverſely, are the cauſe of ſaturation.

Experiments and diagrams explaining the phenomena of inviſible fluids formed by two or more fluids which attractand ſaturate each other; the phenomena of viſible or aqueous fluids formed by two or more inviſible fluids which attract and ſaturate other matter; and thephenomena of ſolid maſſes formed by two or more elaſtic fluids which attract and ſaturate each other: alſo explaining the cauſes of thoſe phenomena, and of all the conditions of ſaturated elaſtic fluids, ſaturated incompreſſible fluids, and ſaturated ſolid bodies, and the cauſes of other intermediate conditions of ſaurated matter.

Experiments, ſhewing the various new appearances and properties different from thoſe of the pure elements, induced by ſaturation: and diagrams explaining how ſaturation muſt neceſſarily induce ſuch appearances and properties, without the aſſiſtance of any powers except thoſe of attraction and repulſion.

Experiments, ſhewing that homogeneal alkali attracts earth.

Eſtimations of the force of this attraction in contact, and at given diſtances, in fortuitous, and in polar arrangement of the atoms.

Experiments ſhewing that the alkaline elements attracts water.

Experimental eſtimations of the force of this attraction.

Experiments ſhewing the levity or weak ſpecific gravitation of the alkaline matter; the ſum of its attractions compared with thoſe of earth and water; the ſum of its repulſions conſidered. The force with which it ought to gravitate, according to the premiſes, eſtimated; and being found to correſpond with the real gravitation of this matter; the gravitation of alkali is to be held as the exceſs of the foregoing attractions above the ſum of the repulſions.

Reaſons why the action of fire on alkali, and various phenomena of alkali on combination, are reſerved for future conſideration.

Of Acids in general, and of the acid Element.

The chemical hiſtory and diſtinctions of acids, in the order in which they ſtand on the table.

Obſervations and experiments ſhewing that all the acids of the chemiſts are compound bodies.

The queſtion concerning the identity of the acid matter ſtated.

Obſervations experiments and arguments *Pro.*

Obſervations experiments and arguments *Contra.*

The arguments *pro* and *contra* weighed. New experiments, and all experiments propoſed in the minute book, to be made with a view to decide on the foregoing queſtion.

A method propoſed, and to be obſerved on the part of the author, whereby the future inveſtigations ſhall not be interrupted, and the future doctrines ſhall not be erroneous, whether there be one or many acid elements; which method is the ſame as is obſerved with reſpect to earth. *(See Earth.)*

Experiments ſhewing, thatacid matter is not commuted or deſtroyed, in any combuſtions or detonations, or in other proceſſes, wherein it is loſt to the chemiſts, and thence ſuppoſed to be deſtroyed: And alſo that it is not generated in effloreſcences, putrefactions, fermentations, &c. but only diſengaged or attracted from contiguous bodies.

Obſervations and experiments ſhewing the acid matter ſolitary or pure, or nearly ſo, and that acid matter is an Element, altho' not heretofore known or noticed as ſuch.

Obſervations and experiments, ſhewing that the atoms of the acid element repel each other; and ſhewing the ratio of this repulſion at given diſtances; and that by reaſon of this repulſion varied with the diſtance, this element is an elaſtic, compreſſible, expanſible, inviſible fluid.

Experiments ſhewing the repulſion of the atoms of the acid elaſtic fluid counterpoiſed by the attraction of other matter, and the formation of fluids of greater denſity, but yet inviſible; And next, the repulſion of the parts cf the acid fluid overpowered by the attraction of other interpoſed matter to the acid atoms, which are thus approximated ſufficiently to form an aqueous fluid; and laſtly, the repulſion of acid atoms ſo much overpowered by the attraction of other interpoſed matter, that ſolid ponderous maſſes are formed therewith.

Modern conceits of *acid air*, *vitriolic air*, *acetous air*, *nitrous air*, &c. corrected. The true cauſes of ebullition, intumeſcence, effervеſcence; and the uſeful application of this knowledge in practice, exhibited.

Experiments and calculations aſcertaining the diſtance to which the repulſion between the atoms of acid can be extended with a force equal to that wherewith they are compreſſed by the atmoſphere. The force of this repulſion further conſidered at greater and ſmaller diſtances.

Experiments and obſervations authoriſing poſitions equally applicable to acid and the foregoing elements; and ſuggeſting that repulſion and attraction, which are forcible in contract, leſs forcible but yet menſurable at various diſtances, do extend to diſtances indefinite

Experiments and inductions, explaining the condition in which acid, like other matter, is inviſible, viſible, fluid, ſolid, compreſſible, incompreſſible; and perſuading that acid, like other matter, reduced to a ſtate in which it eludes vulgar obſervation, is nevertheleſs identical, incommutable, indeſtructible: And that the attractive and repulſive powers of acid as well as of other matter, ſuffer no ſuſpenſions, fits or intermiſſions, and never are commuted in any circumſtance or diſtance, but only balance or overpower one the other, and thus occaſionally ſeem to be deſtroyed, or not to exiſt.

Obſervations and experiments on the acid elaſtic fluid and acid compounds, and inductions confirming the foregoing doctrines concerning elaſticity, fluidity, ſoftneſs, hardneſs, plaſticity, ductility, brittleneſs..

Experiments to determine whether the acid element conveys ſound, which it is expected to do.

Obſervations and experiments ſhewing the polarity of the acid atoms, and the difference of the aggregations formed by fortuitous arrangement, from thoſe formed by polar arrangement, of theſe atoms in combination.

Obſervations and experiments on the acid fluids and acid compounds, and inductions generalizing and confirming the foregoing doctrines concerning ſaturation, its cauſes, and extenſive effects in nature.

Experiments ſhewing that homogeneal acid attracts earth; and experimental eſtimation of the force of this attraction in contact, and at given diſtances, in fortuitous and polar arrangement of the atoms.

Diagrams explaining various phenomena, which at firſt view ſeem repugnant to the foregoing doctrines.

Experiments ſhewing that acid attracts alkali.

Experimental eſtimation of the force of this attraction in contact, and at given diſtances of the atoms.

The incompetency and errors of the tables of elective attractions demonſtrated; and comprehenſive tables commenced, in which the blanks are to be filled up as faſt as experiment will authoriſe.

The ſum of the ſimple attractions and repulſions of the acid element conſidered; and the compound attraction or the gravitation of acid deduced from the foregoing attractions.

The former doctrines concerning fixity, volatility, ſpecific gravity, generalized and confirmed.

Of Air.

Review of the pneumatic experiments, and of the doctrines which are unexceptionable, and ought to be aſſumed on the preſent occaſion.

Experiments and obſervations, ſhewing that atmoſpheric air contains various matters different from the aerial element; ſhewing the difficulty of obtaining any conſiderable quantity of pure air; the errors into which experimental philoſophers have been led, by the impurities of atmoſpheric air; and the methods whereby theſe and other errors may be in future avoided and pure air may be obtained.

Experiments and obſervations ſhewing that the atoms of air repel reciprocally; and eſtimations of the force of this repulſion, in contact and at various diſtances of the aerial atoms

Experiments ſhewing the repulſion of aerial atoms balanced by the attraction of theſe to other interpoſed matter, and the conſequent formation of an elaſtic inviſible fluid of greater denſity than air hath, in like circumſtances of atmoſpheric or mechanical preſſure; and ſhewing the repulſion of aerial atoms overpowered by the attraction of theſe to other interpoſed matter, and the conſequent formation of an incompreſſible, viſible, palpable fluid; and laſtly ſhewing the repulſion of aerial atoms ſo much overpowered by the attraction of theſe to other interpoſed matter, that incompreſſible, palpable, ſolid, ponderous maſſes are formed thereby.

Inductions from the premiſed experiments importing, that the atoms of air, however approximated, combined, or detached from compounds, are never commuted or deſtroyed; that there is but one aerial element; that the repulſion which cauſes elaſticity of air, cannot be impaired by mechanical force as hath been ſuppoſed; that air is not indefinitely compreſſible; that the volume to which a portion of atmoſpheric air can poſſibly be reduced by mechanical force, may be truly eſtimated; and that neither air nor any other known matter attracts at one diſtance and repels at another diſtance; but that air and all known matters attract at every diſtance thoſe bodies which they attract at any diſtance, and repel at every diſtance thoſe bodies which they repel at any diſtance.

Remarks on the pneumatic electrical and other experiments which have led philoſophers into notions repugnant to the foregoing.

Obſervations on the imperfections of the air pump and other pneumatic machines, and on the advantages and diſadvantages of our apparatus.

Experiments to determine whether air which certainly attracts phlogiſticated earths, doth attract or repel homogeneal earth.

Experiments and obſervations ſhewing that air doth attract water.

The phenomena of evaporation, exſiccation, hygrometers, deliquiation, humidity, ſweating walls, and water diſtilled from air; the phenomena which have ſuggeſted the notion of the converſion of mercury and various other bodies into water, &c. &c. deduced from the premiſes.

Eſtimation of the force of this attraction in contact, and at various diſtances of the atoms of air and water.

Queſtion. Doth pure air attract pure alkali, or repel alkali; or neither attract nor repel alkali; which latter may be called neutrality.

Reaſons why neutrality ought to be rejected; and why, as the affirmative of the queſtion implies attraction, the negative implies repulſion.

Experiments, in order to decide* on the queſtion.

Whatever may be the event of theſe experiments, it may be remarked, that neither attraction nor repulſion of air to alkali or pure earth is aſſumed in any part of the following doctrines; that in purſuing nature we ought rather to leap over ſmall obſtacles than loſe ſight of nature by waiting to remove them; and that it is better to paſs the attraction or repulſion of air to alkali or homogeneal earth unnoticed, than to admit a dubious poſition.

Experiments and obſervations, ſhewing that air doth attract acid, and ſhewing the properties of the bodies which contain this combination of acid and air.

The theory of ſaturation further confirmed.

Experiments in order to analyſe the nitrous acid compleatly, and to exhibit the air contained in it.

Compariſons of the attractions and repulſions of air, and of the quantity of matter which attracts air, with the quantity of matter which repels air; and inferences ſhewing the gravitation of air is the effect or rather the ſum of the primary attractions thereof.

Application of the premiſed experiments and doctrines, concerning air and the preceding elements, towards explaining the motions, impulſe, and vibrations of air, our ſenſe of which is expreſſed by the words blaſt, crack, ſound, tones; towards the illuſtration and confirmation of the foregoing theories of viſibility,

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* It is preſumed that a repulſion between air and alkali will be demonſtrated.

lity, inviſibility of matter, and of ſaturation, and of fluidity, ſolidity, elaſticity, &c. and towards explaining the agency of air, in the proceſſes we expreſs by the words tarniſhing, ruſting, mouldering, corruption, rotting.

Review of the experiments which gave riſe to the opinion that the atoms of air are larger than thoſe of water.

The phenomena of theſe experiments, and particularly the free paſſage of water thro' bodies which are not pervious to air, deduced and explained from the premiſes.

Phlogiſton.

Recital of experiments obſervations and arguments repreſenting the imperfections of our ſenſitive organs, and the neceſſity for employing our rational faculties in order to aſſiſt and correct common perception, in the inveſtigation of elements much more ſubtle than the foregoing, as pervading all inſtruments and veſſels.

Combuſtion and ignition experimentally diſtinguiſhed.

Experiments ſhewing that none of the foregoing elements, nor of the bodies compoſed of them, are combuſtible, altho' they may be ignited or charged with fire.

Experiments ſhewing that all the foregoing elements (except water) and all compounds of theſe elements, can be charged with another matter ſo as to become combuſtible.

A claſſical arrangement on the table of earthy, acid, alkaline, aerial bodies, and combinations of theſe, charged, in the ordinary proceſſes of nature, with matter which renders them combuſtible.

Experiments ſhewing the ſame bodies artificially charged with a matter which renders them combuſtible, and that both natural and artificial compounds containing this matter, are in the act of combuſtion deprived of it; and that after this privation they are not combuſtible.

Compariſons of the foregoing elements and compound bodies conſiſting of them, with the like elements and compound bodies charged with phlogiſton; and experiments ſhewing that altho' combuſtibility is a proof of the preſence of phlogiſton; incombuſtibility of bodies is not a proof that they contain no phlogiſton, but only proves that they retain it by the more forcible attractions, or defend it from the agency of air.

Experiments and obſervations, to prove that the phlogiſtic matter in Ethers, ſpirits, oils, balſams, reſins, gums, mucilges, vegetables, charcoal; in all animal ſubſtances; in petrola, amber, aſphaltum, mineral-coal, and all cumbuſtible mineral bodies; in all ores, and metals; and in all known bodies; is transferable to other non-phlogiſtic bodies, and from any one body to another, in certain gradations directly, or in any ſeries by artificial means; forming new compounds with all bodies except water: and this matter after having undergone numerous transfers, combinations, expoſures to fire, &c. ultimately forms with acid, alkali, earth, air; the compounds formed by theſe in native combination with phlogiſton, or by theſe in any artificial combination with the phlogiſton of any body.

Obſervations on the foregoing experiments and other experiments ſhewing, that phlogiſton is a kind of matter ſubtile, elaſtic, inviſible, incommutable, indeſtructible, incapable of decompoſition, differing remarkably from thoſe already mentioned; that phlogiſton is a diſtinct element; and that there is but one phlogiſtic element.

Obſervations on the experiments on phlogiſtic bodies, and freſh experiments ſhewing, that as phlogiſton, in paſſing from theſe bodies, or when detached in theſe experiments, paſſes through the veſſels and eludes common obſervation; the compounds in which it is rendered viſible or palpable, are to be well examined, previous to the further conſideration of this element; that the eye of reaſon may co-operate with common perception, in our inveſtigation of the properties wherewith the phlogiſtic element is endued.

Experiments to ſhew that phlogiſton doth attract air; that this attraction is one of the agents in combuſtion; that air and phlogiſton ſaturate each other, and that the compound of phlogiſton and air hath properties different from thoſe of the component elements. Experiments exhibiting theſe new properties; and diagrams ſhewing they are the neceſſary effects of the attraction of phlogiſton to air balanced by the repulſion ſubſiſting between the ſimilar atoms of theſe elements, agreeable to the doctrine of ſaturation already eſtabliſhed.

Experiments ſhewing that the atoms of phlogiſton and air are approximated by their mutual attractions to each other, inſomuch that both phlogiſton and air occupy leſs ſpace when mixed, than either occupies when pure, under any given preſſure atmoſpheric or mechanical: and that the compound of phlogiſton and air is, in like circumſtances of atmoſpheric preſſure, a denſer fluid than air, and is ſpecifically heavier than atmoſpheric air.

Inductions from the premiſes, and diagrams explaining why phlogiſton and air which attract each other, do not form a ſolid maſs; and why they form an inviſible expanſible compreſſible fluid.

Experiments ſhewing that air ſaturated with phlogiſton is incapable of uniting with phlogiſton.

Inductions from the premiſes and diagrams ſhewing this to be the neceſſary effect of ſaturation, and that, by reaſon of ſaturation, phlogiſticated air doth not aſſiſt in or maintain combuſtion.

Experiments ſhewing that phlogiſticated air combines with bodies which attract either phlogiſton or air, and conſequently combines with bodies which do not attract pure air or pure phlogiſton.

Inductions and diagrams ſhewing this latter property of phlogiſticated air to be the neceſſary conſequence and effect of the laws of nature already explained.

Experiments ſhewing that phlogiſticated air, which is an elaſtic inviſible fluid, not greatly exceeding pure air in ſpecific gravity, forms with other inviſible elaſtic fluids which attract it ſtrongly, ponderous viſible palpable maſſes. Theſe phenomena deduced from the premiſes.

Experiments ſhewing that phlogiſticated air is transferable without decompoſition, from one body to another, and that the number of theſe transfers already diſcovered, is very great; and that the phenomena attending them, correſpond with, and confirm the foregoing doctrines.

Experiments ſhewing various other properties of phlogiſticated air, its fatal effects on animals, its effects on the electric matter, &c.

Recapitulation of the foregoing properties, &c. of phlogiſticated air, *viz.* the ſpecific gravity, compreſſibility, expanſibility, inviſibility, incapacity to maintain combuſtion; the effects in combinations; the gradations of its attractions to other bodies; the circumſtances in which it is formed; the proceſſes in which it is detached; the circumſtances in which it is transferred; the effects of it on animals, on the electric fluid, &c. All ſhewing that phlogiſticated air is the ſame matter or a chief part of the fluids which modern philoſophers call *fixable air.*

Experiments ſynthetic ſhewing that phlogiſticated air, or fixable air, is always compoſed wherever and however pure phlogiſton is mixed with pure air.

Obſervations on the experiments in which fixable air is formed, ſhewing air to be neceſſary and phlogiſton neceſſary for the formation of fixable air; and that no matter, except phlogiſton, and air, and light and the electric matter is preſent in every experiment in which fixable air is formed.

Concluſions from the premiſes, importing, that fixable air may, by heterogeneous admixture, aſſume various appearances; but that fixable air itſelf is a compound of phlogiſton and air only.

Inferences concerning the elaſtic fluids detached in ſolutions, ignitions, combuſtions, fermentations, animal digeſtion, reſpiration; and concerning damps of the miners and of noxious ſubterranean cavities. The varieties obſerved in the kinds of fixable air formed in various circumſtances accounted for; and applications of this knowledge to practice, in experimental and trading chemiſtry, and in the imitation of mineral waters.

Experiments analytic intended to ſhew, that phlogiſticated air may be decompoſed; that it is decompoſed by the means and in the circumſtances neceſſary for the decompoſition of other phlogiſtic bodies; that this decompoſition is a proceſs daily performed by nature; that air and phlogiſton may be diſcovered in all theſe decompoſitions, and no other matter whatever; that the air ſevered from phlogiſton, has all the properties of pure air, and none of thoſe peculiar to fixable air; that the phlogiſton thus ſevered from air, hath all the properties of phlogiſton, and none of thoſe peculiar to fixable air: concluſions that fixable air is a compound, and conſiſts of phlogiſton and air, and of nothing more.

Obſervations on the uſes of fixable air, and the circulation of it in nature, until it is decompoſed, and its conſtituent air is diffuſed in the atmoſphere or elſe-where, and its conſtituent phlogiſton is lodged in bodies, or contributes to the growth maſs and combuſtibility of vegetables.

Eſtimation of the force wherewith phlogiſton attracts air.

Experiments intended to ſhew that phlogiſton attracts alkali and combines with it. The phenomena of this combination and the force of this attraction conſidered, with a view to the theory of ſaturation and the new tables of electric attractions.

Experiments and obſervations ſhewing, that phlogiſton doth attract acid; that theſe ſaturate each other; that the compound of phlogiſton and acid hath properties different from thoſe of the component elements; and that theſe properties correſpond with the doctrines already advanced concerning attraction, repulſion and ſaturation, and tend to eſtabliſh them; inaſmuch as we can have no ſtronger proof of the truth of any philoſophical doctrine, than its conſonance with the natural phenomena.

Experiments ſhewing, that the atoms of acid are approximated by phlogiſtic atoms interpoſed, and that nevertheleſs phlogiſton and homogeneal acid do not form a ſolid maſs, or denſe fluid, but only an elaſtic inviſible fluid.

Inductions from the premiſes and diagrams explaining why the compound of phlogiſton and acid doth aſſume the foregoing form or condition and no other.

Experiments ſhewing, the combuſtibility of this inviſible compound of acid and phlogiſton, and that this compound, like other phlogiſtic bodies, requires the concurrence of air and fire towards its combuſtion. The various phenomena of the combuſtions of this inviſible fluid explained according to the premiſed laws of nature.

Recapitulation of the demonſtrated properties of the compound of acid and phlogiſton, ſhewing that this is the matter which modern philoſophers call INFLAMMABLE-AIR.

Synthetic experiments ſhewing that inflammable air is compoſed whenever pure phlogiſton is preſented to acid pure, or nearly pure; and whenever phlogiſton eſcaping during the ſolution of phlogiſtic bodies, is permitted to carry with it a portion of the acid menſtruum; and whenever acid and phlogiſton are in the ſame inſtant expelled from compounds by fire.

Reaſons why the nitrous acid acting on metals and phlogiſtic bodies, doth not produce inflammable air, except in particular circumſtances; and why the vitriolic marine, or vegetable acid mixed with a fourth or a ſmaller part of nitrous acid, doth not in acting on phlogiſtic bodies, form inflammable air, as the vitriolic or the marine or the vegetable acid unmixed with the nitrous acid always do.

Obſervations on the experiments in which inflammable air is compoſed, or is detached from bodies by Fire; and obſervations on the places and circumſtances in which it is found native; all ſhewing, that acid and phlogiſton are neceſſary to the formation of inflammable air, and that no matter, except phlogiſton acid the elective fluid and light, is common to all, or preſent in all theſe experiments and places, in which inflammable air is formed.

Obſervations on the inflammable air detached or formed in ſolutions, decompoſitions, fermentations, putrefactions, vitriolizations,

lizations, ignitions; in diſtillations of microcoſmic ſalt with phlogiſtic bodies, in diſtillations of oils, æthers, and various phlogiſtic compounds: obſervations on native inflammable air, fire damps, &c. all ſhewing that inflammable air, by reaſon of heterogeneous admixture, doth aſſume various appearances, but that inflammable air is a compound of acid and air.

Applications of theſe doctrines, concerning inflammable air, to chemical practice, and to the art of compoſing artificial mineral waters.

Experiments ſhewing that inflammable air may be decompoſed, and that it is decompoſed in the ordinary courſe of nature.

Concluſions, from the analytic as well as the ſynthetic experiments importing that inflammable air conſiſts of phlogiſton and acid, and of nothing more.

Obſervations on the circulations of inflammable air, and the continuance of theſe circulations, until its acid is drawn away by other matter, and its phlogiſton is attracted by non-phlogiſtic bodies, to form phlogiſtic combinations, or to contribute to the maſs and combuſtibility of vegetables.

Experiments and obſervations ſhewing that phlogiſton attracts earth.

Eſtimation of the force of this attraction in contact and at given diſtances of the atoms.

Comparative eſtimation of the attraction of phlogiſton to earth, to alkali, acid, and air.

Digreſſion concerning alchemiſtic enquiries; vindication of alchemiſts, and cautions againſt the dangers of alchemy.

Examination of the opinions concerning Fire, and particularly the opinion prevalent with modern philoſophers who ſuppoſe that Fire is a certain motion of matter.

Confutations of theſe opinions.

Experiments and obſervations ſhewing that Fire is a matter different from any matter treated of previous to phlogiſton, and that motion is not neceſſary to the exiſtence of Fire.

Experiments and obſervations ſhewing, that the attraction of phlogiſton to the foregoing elements, or bodies compoſed of them, is counteracted, or in effect weakened, by Fire; and particularly that the attraction of phlogiſton to air, is counteracted, or in effect weakened, by the introduction of Fire.

Experiments and obſervations ſhewing that pure phlogiſton doth not attract pure water and is not combinable with water, except by means of ſome matter interpoſed, which attracts both phlogiſton and water, but that phlogiſton nevertheleſs eaſily pervades water.

Inductions from the premiſes explaining, how repellent bodies are combined by means of a third body; and how compounds which will not unite, are by means of a third compound united; and how bodies, which will not cohere, are, by means of a third body, made to cohere; and explaining various other phenomena, which may be ranked under the following heads, *viz.* Intermediums, cements, wetting, ſcouring, inflammable bodies ſoluble in water, inflammable bodies not ſoluble in water.

Experiments and obſervations ſhewing that the atoms of phlogiſton attract other atoms more forcibly in one axis of each atom than in any other; or, that phlogiſton like other elementary matter hath polarity.

Experiments ſhewing that many non-phlogiſtic bodies, accurately weighed, and then combined with conſiderable quantities of phlogiſton, acquire no additional abſolute gravity by this acceſs or addition of phlogiſton.

Other experiments indicating that the abſolute gravity of many non-phlogiſtic bodies, is conſiderably counteracted or in effect leſſened by combining theſe bodies with phlogiſton; and ſhewing that theſe bodies, whoſe abſolute gravity hath been leſſened in the foregoing manner, acquire or reſume a greater abſolute gravity, when they are deprived of phlogiſton: inferences from theſe experiments perſuading that pholgiſton doth not gravitate, and that it hath a power whereby it counteracts the gravitation of other matter; unleſs the bodies whoſe gravity is encreaſed whilſt they are deprived of phlogiſton, attract and combine with air which cannot be extricated or diſcovered by any known art.

Eſtimations of the known attractions and repulſions of phlogiſton; of the relative quantities of different kinds of matter in the terraqueous globe which attract phlogiſton, and of the quantities of matter in the terraqueous globe which repel phlogiſton.

Concluſions implying that the ſum of the repulſions of phlogiſton, may exceed the ſum of the attractions; and that phlogiſton may not gravitate; and ſince it ſeems not to gravitate, that the foregoing theory of gravitation is further confirmed.

The levity and volitility of æthers ſpirits oils and various inflammable bodies, and other phenomena of a ſimilar nature occuring in the practice of chemiſtry in arts and in the great elaboratory of nature, deduced from the premiſes.

Compariſons of the ſpecific gravity of phlogiſtic bodies with that of other bodies: arguments in addition to thoſe already uſed, perſuading, that ſpecific gravity and denſity are not commutable terms, as the moſt celebrated philoſophers have aſſumed and uſed them; that there is not neceſſarily more matter in a cubic inch of glaſs than in a cubic inch of reſin, nor larger pores or interſtices in the reſin than in the glaſs; although the ſpecific gravity of glaſs be much greater than that of reſin; and finally that gravity depends as much on the ſpecies of the gravitating bodies, as on the quantity of them.

Experiments and obſervations ſhewing that phlogiſton, when detached in ſaturations fermentations decompoſitions native vitriolizations, in combuſtions culinary chemical phoſphoric, in colliſions frictions, &c. is either Fire, or is a conſtituent ingredient of Fire.

Experiments and obſervations ſhewing that phlogiſton, whether in combination, or detached, is *not* Fire; that Fire, whether in bodies, or parted from them, is not phlogiſton; and that Fire differs from phlogiſton, as much as any know compound differs from its component heterogeneal parts.

Inductions implying that ſince phlogiſton is not Fire, but is a conſtituent ingredient of Fire, Fire is a compound body conſiſting of phlogiſton and ſome other matter.

Enumeration of the former experiments which ſhew that the bodies formed with phlogiſton, and the homogeneal bodies and compounds hitherto examined, are totally different from Fire; and enumerations of the exhibited properties of all the elements and compounds treated of previous to phlogiſton, ſhewing none of theſe can be an ingredient or component part of Fire.

Inductions perſuading that as fire is a compound containing none of the foregoing elements except the phlogiſton now under conſideration, and as we know no other element, ſaving Light, wherewith phlogiſton can form a compound poſſeſſing the properties of Fire; we may reaſonably preſume that Fire is compoſed of phlogiſton and Light, and of no other matter whatever.

A digreſſion concerning Light and the properties of it which relate to the preſent ſubject.

The firſt twenty paragraphs on Light will announce the ſubjects of this digreſſion.

Experiments and obſervations ſhewing, that Fire hath properties different from thoſe of phlogiſton and from thoſe of Light, and correſponding with the doctrine of ſaturation; that the general properties of Fire are intermediate between thoſe of phlogiſton and Light, in the ſame manner as the general properties of other compound bodies are intermediate between thoſe of their component parts; and that we are led, by general analogy, to conſider Fire, as a compound of phlogiſton and Light.

The arguments *a priori* and the arguments from analogy, ſupported by arguments *ex abſurdo*, perſuading that Fire is compoſed of phlogiſton and Light.

The foregoing doctrine further ſupported on the following grounds: that it is preſumed to correſpond with the natural phenomena; that nothing will appear repugnant to it in our future experiments; that by admitting it, we ſhall explain appearances which ſeem otherwiſe inexplicable, and we ſhall be enabled to prognoſticate the reſult of many new experiments.

Reaſons for not introducing theſe teſts in this place; and why theſe teſts, wherever introduced, render the doctrine as credible as any other admitted in natural philoſophy.

Obſervations and experiments ſhewing, that phlogiſton doth attract Light; that theſe ſaturate each other; and that it is poſſible truly to eſtimate the force of this attraction, in the ſame manner as the attractions of other elements have been eſtimated.

Experiments on combuſtion, ſhewing the circumſtances neceſſary thereto.

EXPERIMENTS.

Firſt, On bodies which for their combuſtion require no ignition: *ſecondly*, on bodies which for their combuſtion require nearly the quantity of ignition given by a flint-ſpark: *thirdly*, on bodies which for their combuſtion require nearly the quantity of ignition given by tinder: *fourthly*, on bodies which for their combuſtion, require nearly the quantity of ignition given by the blaze of a taper; *fifthly*, on bodies which for their combuſtion require the ſeveral intermediate degrees of heat, between thoſe of the taper and of the fierceſt furnaces.

Experiments exhibiting the combuſtions which are extremely ſlow, and are accompanied with no perceptible heat: experiments exhibiting the combuſtions which are quicker, in their progreſs, than the foregoing, and are accompanied with various degrees of heat: experiments exhibiting the combuſtions which are rapid in their progreſs, and are accompanied with intenſe heat: all exhibiting the agency of air in combuſtion; the inefficacy of phlogiſticated air, and the retardation of combuſtion, by every means whereby the air meets impediment.

Experiments ſhewing that ſome phlogiſtic bodies may, by the gradual application of Fire, be ſooner evaporated than inflamed, even in the preſence of air; but may ſooner be inflamed than evaporated, by any other application of Fire, in concurrence with air; and further ſhewing that ſuch bodies conſiſt of repellent elements, are weakly aggregated, gravitate weakly, and are eaſily volatilized by Fire.

Experiments exhibiting detonations and exploſions; commencing with thoſe of ſmall force and ſlow progreſs, and proceeding thro' numerous gradations, to thoſe which are inſtantaneous and forcible in the higheſt degree; exhibiting alſo the elementary matters concerned in theſe exploſions, and the manner in which they operate on each other, to cauſe exploſion, and various other phenomena.

Experiments and obſervations on burning lamps, candles, flambeaux, &c. The combuſtions of oils, tallow, ſpermaceti, wax, &c. compared. Obſervations on the uſe of wicks. Obſervations on the commencement and progreſs of theſe combuſtions. Obſervations on the extinctions and revivals of theſe combuſtions, by currents of air and other means.

Obſervations on the phenomena accompanying the formation of burs or ſnuffs, and various poſitions of wicks.

Experiments exhibiting the phenomena of combuſtions checked by water or ſucculence, and of combuſtions extinguiſhed by water, fixable air, and other fluids.

Experiments exhibiting the unextinguiſhable combuſtions.

All the foregoing phenomena of combuſtion, detonation, exploſion explained; and ſhewed to be the neceſſary reſult of the various kinds, and of the ſpecific properties of matter already mentioned; confirming the preceding doctrines, and particularly that of fire.

Experiments and inductions ſhewing that the intenſity of Fire, is in the direct ratio of the quantity of Fire compoſed or retained in any given ſpace, in every inſtant of time; and that every degree of Fire or heat, from that which we call temperature, up to the furnace heat, hath the like relation to time and ſpace.

Experiments and inductions ſhewing that blaze differs from Fire, in its properties and in its compoſition: and ſhewing that blaze is a *mixture* of Fire and phlogiſtic matter which hath not yet been decompoſed, ſo as to contribute to the formation of Fire.

Experiments exhibiting various phenomena of ſmoak, ſoot, and the reſiduary matter of combuſtions

Inductions from theſe experiments, and obſervations on combuſtion, Fire, blaze, ſmoak, ſoot and reſiduary matter; confirming the foregoing doctrines, and uſeful or explanatory in arts.

Inductions from the foregoing experiments, importing, that air is not a neceſſary ingredient in Fire; that it is not a *pabulum ignis*, as philoſophers have imagined; and that it is no otherwiſe neceſſary in combuſtion, than as an agent, in the extrication of phlogiſton, from the other matter of combuſtible bodies.

Experiments ſhewing the different effects of furnaces differently conſtructed; how furnace heats, greatly exceeding thoſe heretofore known, may be excited; how Fire may, moſt equally and conveniently, be applied to large maſſes of matter, and to great diſtances; how to manage fuel to the greateſt advantage; and how to make choice of fuel for various purpoſes.

Theory of the draught of chimnies, of the conſtruction of furnaces, kilns and fire-places; and theory of the other ſubjects of the laſt paragraph; founded on the premiſed experiments and properties of matter.

The management, uſes and effects of the blow-pipe, ſhewed and explained.

Experiments and obſervations pointing out improved methods of burning ſmoak; of extinguiſhing accidental fires in certain circumſtances; of curing ſmoaky chimnies, however ill conſtructed, by alterations in the ſtoves only; and pointing out improvements in arts which require the application of Fire.

Experiments and obſervations ſhewing that Fire is an elaſtic fluid; that this elaſticity is a neceſſary effect of the demonſtrated Properties of phlogiſton and light; and that the power which cauſeth this elaſticity, is repulſion; which is the cauſe of elaſticity in other fluids.

The theory of ſaturation introduced, and diagrams preſented in order to ſhew more clearly, why Light, which attracts phlogiſton, doth not form therewith a ſolid maſs, or denſe fluid, but an elaſtic fluid.

Review of the experiments which ſhewed the ſubtility of phlogiſton and of light; and inductions importing that the capacity, which Fire hath to pervade all bodies, is the neceſſary reſult of the demonſtrated properties of the component elements of Fire; and that from this property of Fire no exception ariſeth againſt the doctrine of ſaturation; inaſmuch as that doctrine doth not teach that the ſize of elementary atoms can be altered, nor that molecules can be formed until the atoms are in contact.

Inductions from the properties of Light and phlogiſton, and from various experiments and obſervations on Fire; importing that Fire is capable of receiving and communicating motion.

Experiments and obſervations ſhewing, that bodies whoſe ultimate parts are held in contact by the more forcible attractions, are leaſt expanded by a given charge of Fire; that fluids whoſe atoms are approximated by the leſs forcible attractions, are moſt expanded by the like charge of Fire; and that ſolids or fluids, whoſe atoms are cloſely approximated, or held in contact by attractions, intermediate between the foregoing, in force, are expanded to degrees intermediate between the foregoing, by the like charge of Fire.

Experiments and obſervations ſhewing, that ſolid bodies, which are expanded by a ſmall charge of Fire, are ſoftened by a greater charge of Fire, are rendered fluid or fuſed by a charge of Fire ſtill greater; and are thrown into vapour, by a charge of Fire much greater than the foregoing charges.

Experiments and obſervations ſhewing, that fluids are expanded by a ſmall charge of Fire; are thrown into vapour expanding with ſome force, by a greater charge of Fire: and that this vapour is made to expand with much greater force, by much greater charges of Fire, than the foregoing.

Theory of the Thermometer.

Conſiderations of the foregoing experiments and obſervations: —Conſideration that Fire cannot deſtroy attractive powers.—Conſideration that attraction is moſt forcible in contact, and decreaſes in ſome regular inverſe ratio of the diſtances of the atoms:—Inductions from theſe experiments and facts, importing

ing, that Fire hath the power of counteracting attraction, by reaſon of its capacity to remove contiguous atoms of bodies to a diſtance from each other. Inductions in like manner importing, that hardneſs, ſoftneſs, fluidity, and the vaporous ſtate, to which bodies are reduced by Fire, are effects; the firſt, of powerful attraction in the contact of the atoms; the ſecond, of attraction counterpoiſed; the third, of attraction weakened by diſtance; the fourth, of attraction weakened very much by reaſon of the greater diſtances between the atoms.

Experiments ſhewing that fire, applied contiguous to a body, and not confined by that body; but on the contrary left at liberty to expand and diffuſe itſelf on all ſides, except on the coaſt of that body; will nevertheleſs expand that body, however ſolid and tenacious it may be. Compariſon of theſe things, with the aſſertions, *that Fire is matter, and that it is an elaſtic fluid.*

Queſtions ariſing from the foregoing experiments and aſſertions, viz. Why doth not Fire flow off on the ſide where it finds leaſt reſiſtance? Why doth Fire, which is at liberty to flow off on all ſides, except one, nevertheleſs enter a ſolid body, and expand it, in deſpite of the forcible attraction whereby the atoms of that ſolid body reſiſt ſeparation?

Theſe queſtions anſwered conſiſtently with the premiſes.

Inductions explaining how Fire ſevers the atoms of bodies from each other; how it expands, ſoftens, fuſes, and vaporates bodies.

Conſiderations on various occurrences in chemiſtry and arts, ſuggeſting, that the force of Fire, in expanding bodies, is not indefinite. Experiments in order to examine the truth of this ſuggeſtion.

Obſervations on the uſe and abuſe of the word *heat*; and ſhewing, that it expreſſes only our ſenſe of certain *effects* of Fire; and that if *latent effect*, or *latent ſenſe*, are expreſſions contradictory and unphiloſophic; the phraſe *latent heat*, conveys no clear ideas, and ought never to be uſed in chemiſtry or natural philoſophy.

Experiments and obſervations ſhewing that heat, and degrees of heat, are as the quantities of Fire in the bodies or ſpaces.

Review of the experiments and natural proceſſes, in which phlogiſton is detached and doth not form Fire; and of the experiments and natural proceſſes, in which phlogiſton is detached and doth form Fire.

Obſervations on the times, diſtances, and circumſtancs in which the effects of Fire do ceaſe; and on the transfers and privations of Fire.

Inductions importing that cold is privation of fire; and further, that the powers whereby phlogiſton, detached from combuſtible bodies, is prevented from forming Fire; may effect the decompoſition of Fire.

Experiments and obſervations, purſuant to the foregoing inductions, intended to ſhew that Fire is actually decompoſed, in various artificial and natural proceſſes; and that this decompoſition of Fire, is one of the cauſes, whereby cold is produced.

Experiments ſhewing that when a body is ſuddenly expanded, by reaſon of the repulſion of its parts, or by any power except that of Fire; then cold is produced in that body, and in the vicinity of it.

Experiments ſhewing that when any body is ſuddenly contracted in its dimenſions, ſo far as to occupy a ſpace much ſmaller than it did in its former ſtate; then heat is produced in that body and in the vicinity of it.

Theſe and all known productions of heat and cold, explained, and deduced from the premiſes.

Inductions importing that heat is produced in two ways: *firſt*, by the formation of Fire; and *ſecondly*, by compacting the Fire, which was diffuſed in a voluminons body, into a ſmall body or ſpace. Inductions importing that cold alſo is produced in two ways: *firſt*, by the decompoſition of Fire; *ſecondly*, by cauſing the fire, which was contained in a ſmall compaſs, to expand to a large compaſs.

Experiments and obſervations on the circulations of phlogiſton; from the compound called Fire, to the bodies in which it is lodged, therewith forming inorganic combuſtible bodies; and from the compound called Fire, until it contributes to the vegetation and maſs of combuſtible vegetables.

Enumeration of various natural and artificial operations, and of phenomena, which have not been noticed ſufficiently in the preceding inveſtigations: Reaſons why theſe ſubjects may be now conſidered, in any order; and why they may be propoſed in the form of queſtions; in order to ſhew, that the anſwers to theſe queſtions muſt be derived from the foregoing doctrines, and no others; and conſequently that theſe anſwers confirm the premiſes; inaſmuch as the credibility of all doctrines in natural philoſophy, is founded on their conformity with, and their explication of, the natural phenomena.

Queſtions.

Why is there no encreaſe of heat in the terraqueous globe or in the vicinity of it; in conſequence of the quantity of fire hourly formed, in the courſe of many thouſand years?

Why is their no apparent waſte of this our globe; and why is there no deficiency of phlogiſtic matter; in conſequence of the waſte of phlogiſtic bodies in burning, and of the vaſt quantities of phlogiſtic matter hourly formed into Fire?

Why are the higher regions of the atmoſphere, colder than the lower regions; although Fire is evidently buoyant in air?

Why doth the heat of combuſtions not extend, in open quieſcent air, to any conſiderable diſtance, either horizontally or vertically: and why the heat of combuſtions doth not extend to any great diſtance, even with the wind?

Why Fire may, without notable waſte, be carried to a great diſtance from burning bodies, by means of chimnies and tubes of maſſive conſtruction; and why Fire is carried from burning bodies, to the diſtance of many miles, in ſubterraneous cavaties, without notable waſte?

What is the cauſe of meteors, fire balls, and luminous miſts?

Why doth Fire affect an equlibrium in bodies and ſpace; and why doth it appear to have no very conſiderable appetence or attraction to any one maſs of matter, above any other, ſo as to heat them unequally?

What is the cauſe of condenſation?

Why doth our new recipient, capable of containing only a quart of water, ſerve to condenſe as much vapour, in a given time, as can be condenſed in a receiver capable of holding one hundred quarts or more?

Why are heavy bodies carried away by Fire, in a direction contrary to that of their gravitation; or in any direction from the focus of the Fire?

Why doth Fire decompoſe compound bodies; and effect combinations, and decompoſitions, otherwiſe not feaſible; and often contrary to the order of the more forcible attractions.

Why bodies, which reſiſt the volatilizing power of Fire, with extreme force, are eaſily volatilized, by Fire, when they are combined with phlogiſton?

Why do water, ſpirits, and other bodies, when vaporated by Fire, mount in atmoſpheric air: and why do they mount to a certain height in the atmoſphere of air, and no further?

What is the cauſe of hail, ſnow, and what the moſt general cauſe of winds and monſoons?

What are the cauſes of fermentation, putrefaction, decay, efflorefcence, inteſtine motion and effervefcence?

What is the cauſe of the petrefaction of wood, &c.

Why are putrid bodies odorous? And why are many bodies not odorous until they are ſtruck, rubbed, or heated?

Why are putreſcent bodies, long preſerved from putrefaction, by fixable air?

Why is wood long preſerved from rotting, by immerſion in water?

What is the condition of air, when it accelerates putrefaction?

Why is the air in cities, woods, marſhes, cloſe priſons, and ſhips, leſs ſalubrious than the atmoſpheric air in other places?

Why is the air which hath been reſpired, inſalubrious to animals which immediately breathe it?

What is the power, whereby potential cauſtics deſtroy the human fabric, &c. &c.

Of Light.

Review of the experiments and doctrines of Sir *Iſaac Newton* and other philoſophers, concerning Light. Vindication of Sir *Iſaac Newton*, from erroneous opinions aſcribed to him, in conſequence of his Queries.

Various fallacies and inconſiſtencies of the modern theory of optics exhibited.

Experiments and obſervations perſuading that Light is an elementary matter conſiſting of atoms of the ſmalleſt ſize: That Light is not an emanation, or a matter ſent forth by the ſun, or ſtars, or planets, or ſatellites: That Light exiſts in all bodies and ſpaces to the utmoſt limits of the known creation: That Light viſible, or illumination, is the element of Light impreſſing our organs of ſight ſenſibly: That darkneſs is not the abſence of light, or any privation of light: That darkneſs is a word by which we ought only to expreſs our inſenſibility of the preſence of Light: that the quieſcence of Light is the cauſe of darkneſs; or in other words, darkneſs is Light at reſt, or in a condition incapable of making a ſenſible impreſſion on our organs: That illumination (commonly called Light) and darkneſs, are with reſpect to Light, what ſound and ſtillneſs are with reſpect to air.

Obſervations on the errors induced in optical reaſoning, by confounding the ideas of illumination, and Light; by uſing the word Light indiſcriminately to expreſs the element, and our ſenſe of its motion; by the like improper uſe of the words darkneſs and ſhade. Experiments and obſervations concerning ſhade, ſhewing what it really is, and the impropriety of denying the ubiquitiy of Light, becauſe illumination, vulgarly called Light, doth not bend into the ſhade.

Experiments and obſervations, ſhewing that Light is an element conſiſting of atoms which repel each other; and that by reaſon of this repulſion, together with the ſubtility already mentioned, it becomes an elaſtic fluid, capable of pervading all bodies, and is itſelf inviſible, although it be the medium of viſion.

Experiments and obſervations indicating that Light doth not attract earth or earthy compounds, water or watry compounds, alkali or alkaline compounds, acid or acid compounds, air or aerial compounds, nor compounds conſiſting of two or more of the foregoing, nor any known viſible matter, nor any known inviſible fluid, or matter, except phlogiſton; but that on the contrary, Light repels all theſe bodies and every known matter, except phlogiſton.

Speculations concerning the repulſions of Light, the attraction of Light to phlogiſton, the relative quantities and conditions of matter attracting and matter repelling Light; Inferences that Light ought not to gravitate to our earth, if gravitation be only the ſum of the ſimple attractions, or the exceſs of theſe attractions above the repulſions, as hath been ſuggeſted.

Experiments and obſervations ſhewing that light doth not gravitate; and why it is ſo equably diffuſed in bodies and in ſpace.

Experiments and obſervations, ſhewing that we have no ſenſe of illumination, or of objects by viſion (or in the vulgar phraſe we cannot ſee Light) except when Light is actuated by ſome matter in motion: and further ſhewing, that only one ſpecies of elementary matter is capable of thus actuating Light ; and that this matter is phlogiſton ; and that phlogiſton combined with any matter except Light, hath not this property during the combination ; but that pure phlogiſton and phlogiſton combined with Light, that is Fire, have this property ; and have it only whilſt they are in a ſtate of vibratory motion.

Enumeration of the foregoing experiments, and other experiments and obſervations ſhewing, that Light is not moved rapidly and progreſſively in the ordinary courſe of nature, or when it impreſſes us with viſual ſenſe of objects ; that no progreſſive motion of Light is neceſſary to viſion ; but that vibratory motion of Light is neceſſary to viſion : that this motion is communicated to Light by other matter whoſe motion is vibratory : that Light affects the eye by communicated vibratory impulſe, as air affects the ear by the like impulſe, and not by progreſſive motion : and that Light hath no laws of motion except what are common to all elaſtic fluids abſtracted from their gravity.

Review of the ſeveral experiments obſervation and doctrines, which incline us to reject the opinion, that the ſun is a maſs of fiery matter, or that he can emit from his ſubſtance the Light or Fire perceived when he is preſent, and yet ſuffer no waſte or change: and which incline us to to preſume that the ſun is a maſs of matter, not unlike our earth, containing much phlogiſton ; and a great part of whoſe ſurface is at once burning, and whoſe Fire is decompoſed, and whoſe phlogiſton returns to parts of his maſs formerly burnt, and whoſe ſubſtance is conſequently never diminiſhed ; and whoſe Fire, altho' it doth not paſs away from his atmoſpher,e actuates Light to great diſtances, as our ſmall fires upon earth do to ſmaller diſtances, or as they would probably do to greater diſtances, if viewed vertically through the atmoſphere, inſtead of being viewed through the turbid air near the earth.

Inductions from the experienced properties of water, air, alkali, acid, phlogiſton, and Light ; ſhewing why impulſe communicated to all gravitating matter, whether in the form of ſolid maſſes, or inviſible fluids, is to our ſenſes loſt in a ſmall time and ſpace ; and hath, within the ſpace, in which it is perceptible, ſlow ſucceſſive communication or progreſs ; and why impulſe communicated to Light is communicated through this fluid moſt rapidly to diſtances unmeaſured ; and why it is communicated through pure air, and through many other elaſtic fluids, nearly as well as through ſpaces void of air; through ſome ſolid bodies, not ſo well as through air; and through other bodies, not in any degree ſenſible to our organs.

Experiments exhibiting the following phenomena and analogies, which for the preſent are expreſſed by the cuſtomary terms to avoid prolixity, viz.

The phenomena of reflected Light, and reflectors perfect and imperfect; of the angle of reflection; and of parallel, diverging, and converging rays of Light; and of foci of Light by reflection. The analogy between theſe and ſound, and eccho, and bodies cauſing iterations and increaſe of ſound; and the differences of theſe, by reaſon of the defect of gravity in Light, and of the ſubtlety of it in compariſon with air.

The phenomena of illumination propagated through bodies diaphanous in divers degrees: of tranſmitted rays, diverging, parallel, or converging: of foci of tranſmitted rays. The analogy between theſe and ſound communicated through the like bodies; and the limitation of this analogy, by reaſon of the ſubtlety of Light, and the condition of it in bodies. The phenomena which ſuggeſted the notions entertained by philoſophers concerning fits of eaſy reflection, and fits of eaſy tranſmiſſion, and ſerpentine motions of the rays of light. The phenomena of bodies placed in the foci of tranſmitted rays, and of the cold focus of tranſmitted moon-light.

The foregoing phenomena explained and deduced from the premiſed properties of Light and other matter; and the other properties attributed to Light, rejected.

The phenomena of the refractions and inflections of Light reſumed: compariſons of the refracting power of phlogiſtic bodies, with that of non-phlogiſtic bodies; and the reflecting power of non-phlogiſtic bodies compared with that of phlogiſtic bodies. The opacity and blackneſs, of certain phlogiſtic bodies, and their incapacity to reflect Light ſo powerfully as others do; and the capacity of diaphanous phlogiſtic bodies to refract Light more than other bodies do, exhibited.

Explanations of theſe phenomena deduced from the premiſed properties of Light, phlogiſton and other matter.

Experiments exhibiting the phenomena of priſmatic colours, and colours by reflection; and of the colours of bodies; and of colours induced and changed in bodies.

Explanatory review of the laws of motion, and of the phenomena of motion propagated by elaſtic bodies.

The foregoing colours and changes of colour, explained, and deduced from the premiſed properties of Light and other matter.

The received doctrine of colours oppoſed by experiments: and obſervations on theſe and the preceding experiments, perſuading that Light doth not conſiſt of rays or parts differing in their original properties, and impreſſing us with a ſenſe of colour peculiar to each different ray; but that our ſenſe of colour is, our preception of the different *modifications* of the vibratory motion of Light; and that the ſeven priſmatic colours are, with reſpect to Light, what the ſeven tones are with reſpect to air.

Experiments exhibiting the natural phoſphori, and the preparation and phenomena of all the other known phoſphori. The phenomena of phoſphori explained and deduced from the premiſed properties of Light and other matter; or efforts made to this effect.

Conſiderations on the circulations of Light, with a view towards explaining why there is no encreaſe or decreaſe of the quantity of Light; and ſuggeſting ſatisfactory anſwers to various queſtions concerning ſun-light, moon-light, candle-light, &c.

Review of the experiments and proceſſes, in which heat is produced by mixtures, condenſations, fermentations, putrefactions, friction, percuſſion.

Review of the experiments exhibiting the various modifications of luminous and fiery matter in the gradations from the torrid focus of ſun Light, to furnace fires, blazes, &c. down to the cold phoſphoric bodies; review of the properties of phlogiſton and its circulation in our atmoſphere and terraqueous globe; and review of the bodies which become odorous by friction percuſſion or heat; introductory to the experiments preſenting the phenomena of the electrical matter.

The following queſtion propoſed:

Doth the electrical fluid contain phlogiſton?

Obſervations on the materials operations and circumſtances neceſſary for exciting, accumulating, retaining, and conducting the electric matter: and ſummary view of all the phenomena and arguments, which incline us to believe, that the electrical fluid conſiſts chiefly of Light.

Summary view of the obſervations and arguments, which ſeem repugnant to the foregoing opinion cocerning electrical matter. Attempts to reconcile theſe with the affirmative obſervations and arguments; and to eſtabliſh the opinion that Light is a conſtituent part of the electrical fluid.

Experiments and obſervations, made with a view to diſcover, whether the electrical matter is homogeneal Light, or Light combined with phlogiſton; or whether the electrical matter is an homogeneal matter different from all thoſe heretofore mentioned.

Summary view of the foregoing obſervations and doctrines concerning attraction.

Obſervations on the ſeveral ſpecies of attraction adopted by philoſophers, and expreſſed by the words

Attraction of gravitation,
Attraction of aggregation,
Attraction of coheſion,
Attraction of intermediums,
Elective attraction,
Double elective attraction,
Capillary attraction,
Magnetic attraction,
Electrical attraction.

Theſe ſeveral attractions illuſtrated by experiments, and explained, and deduced from the exhibited attraction of the atoms of the ſeveral elements.

Quer. Is it not poſſible for men to arrive to a ſatisfactory knowledge of all the properties of matter hitherto mentioned, and to explain all the phenomema hitherto noticed or implied.

Quer. It is poſſible for the mind of man to inveſtigate the ſecondary cauſe of vital heat, muſcular motion, and ſenſation; even after he hath diſcovered the fluid by whoſe mediation the ſoul actuates the parts of his ſyſtem? What is that life, which a vapour, an elictric ſpark, or a bodkin can detach in an inſtant?

Why is fixable air or phlociſticated air, which extinguiſhes blaze and conducts electric matter, deleterious to animals which take a full inſpiration of it.

Why do æthers, ſpiritus rectors, vinous ſpirits, the vegetables called narcotic, the vegetable and animal ſubſtances called antiſpaſmodics, affect our ſpirits and ſenſes; and why is the moſt inflammable or phlogiſtic part of all theſe, when ſeparated from the other parts, the moſt powerfully narcotic or antiſpaſmodic or exhilerant?

Is there any inſtance of a narcotic ſubſtance that does not abound with phlogiſton?

Why doth air, of a certain temperature, according to the thermometer, give us ſenſe of cold, much greater, than is given by air of the like temperature, according to the thermometer, in other conditions of the atmoſphere. Or in other words; what is the cauſe, that we are chilled by air, which the thermometer denotes not to be ſo cold as air otherwiſe conditioned, in which we are not chilled.

Apology for the imperfections and errors of this Syllabus, and the improvident uſe of affirmative expreſſions in dubious doctrines.

E R R A T A.

Page.	Line.	
17	5,	*dele* without exception
17	17,	*dele* ral
34	2,	*for* gelati, *read* gelatinous
34	16,	*for* juxta poſition, *read* juxtapoſition
49	14,	*for* ſel, *read* vel
50	4,	*for* quæqua, *read* quæque
51	3,	*for* vicinia, *read* vicina
62	7,	*for* ſubject, *read* ſubjects
63	19,	*for* flags, *read* ſlags
66	6,	*for* iſickles, *read* icicles
82	2,	*for* looſes, *read* loſes
—	14,	*for* looſes, *read* loſes
101	13,	*for* ſilicium, *read* ſilicum
103	10,	*for* ſtalectites, *read* ſtalactites
131	20,	*for* partularum, *read* particularum
132	4,	*inſtead of* ; *place* ,
——	15,	*inſtead of* ; *place* :
——	22,	*inſtead of* ; *place* ,
——	24,	*inſtead of* ; *place* ,
162	4,	*for* are, *read* is
——	20,	*inſtead of* ; *place* ,
——	23,	*inſtead of* ; *place* ,
173	10,	*dele* re
——	25,	*dele* the
175	21,	*dele* certain
183	19,	*inſtead of* , *place* .
214	16,	*for* fluids, *read* fluid
221,	laſt line,	*dele* ,
244	9,	*dele* of
256	11,	*after* Euler, *read* our learned Dr. *Franklin*

INTRODUCTION.

SECT. I.

CONSIDERING that Nature is ever conformable to herſelf, and that reaſoning from analogy is of great uſe in Natural Philoſophy; and ſeeing that Light and groſſer bodies act on each other, and that Light is not totally exempt from the laws which govern other matter; I have thought that all thoſe who wiſh to co-operate in the enquiry concerning Light, ought to be previouſly agreed in ſome common notions of the parts and properties of matter in general; and as the notions which are the moſt likely to aſſiſt us in tracing the reciprocal relations of

Light and other matter, and in explaining the optical phenomena, have not been clearly propoſed by any writer known to me, I ſhall inſiſt on theſe chiefly in this introductory part ; and for the ſake of order, ſhall briefly mention a few others which are generally received.

SECT. II.

Definitions.

BY miſcroſcopic obſervations, and in a variety of natural and artificial proceſſes, particularly in thoſe wherein ſolid bodies are greatly expanded by Menſtrua, Fire and other means ; we learn that every perceptible portion of matter is diviſible into parts exceedingly minute, and ſeverally inviſible.

As all Bodies are compoſed of theſe, and all natural operations are conſequently performed by them, it is highly incumbent on us to guard againſt falſe notions of them, and eſpecially againſt the confuſion reſulting from the miſapplication of *infinite diviſibility*, which may well be aſſumed by Mathematicians who treat of Extenſion and Magnitude, but ought to have no place in our ideas of the material parts of bodies; becauſe we can have no diſtinct notions of a body indefinitely ſmall; and becauſe in phyſical enquiries, every diviſion, minuteneſs, or condition of matter, which is not deducible from experience, or neceſſary towards explaining the natural phenomena, is to be rejected.

Avoiding therefore every ſpeculation concerning Ideal diviſions, I conſider the ſmalleſt parts, into which any maſs of matter is ever divided in the proceſſes of Nature or Art, as the *ultimate parts* of that maſs, and as ſmall bodies which are incapable of actual diviſion or diminution.

Theſe minute bodies are very aptly called *Atoms*; and uſing the word *Atom* in this ſenſe, I expreſs by it no more nor leſs, than what really exiſts.

A body conſiſting of two coherent and heterogenous atoms, I call a *Molecule*, after the example of modern chemiſts ; and ſmall bodies, compoſed of an unknown number of cohering atoms, are by common conſent called *Particles*.

By common obſervation and chemical analyſis, we learn that there are many maſſes of matter, which differ from each other in their appearances and properties, and by theſe differences are diſtinguiſhable into ſeveral kinds.

The maſſes or bodies which, in any known proceſs, are ſeparable into parts diſſimilar in their properties, are called *Compound* Bodies: And thoſe, whoſe ultimate parts or atoms, whether cohering or diſtant, are ever found to be ſeverally endued with the ſame properties, we call *Homogeneal* Bodies.

By the word *Element*, I expreſs the whole natural quantity of any ſort of Matter, whoſe ſeveral parts poſſeſs the ſame properties.

Attractive Matter, is that whoſe atoms attract each other.

Repellent Matter, is that whoſe atoms repel reciprocally.

The power which tends to draw together any two atoms, or any two bodies, each of which is homogeneal, is called a *ſimple power of Attraction*; and the attraction is named *Simple Attraction.*

The Attractions of compounded bodies are called *Compound Attractions*; and the powers which effect theſe compound attractions, are denominated *Compounded Powers.*

The *Polarity* of matter is the tendency of the atoms to attract each other more forcibly in one direction or axis of each atom, than in any other imaginable direction or axis thereof.

SECT. III

Diſtinctions of Matter, and Advices concerning Seven Elements of Matter.

THE moſt experienced Philoſophers acknowledge, that the action of Light and groſſer bodies on each other, varies with the kind of matter, as well as with the denſity of the ſeveral bodies; and the enſuing pages will ſhew it is as neceſſary in Optics as in Chemiſtry, that we ſhould diſtinguiſh and aſcertain the number of the elements.

I do not intend, on this occaſion, deeply to engage in an enquiry ſo extenſive, and which demands many new experiments: but with a view to the uſes which I intend to make of the knowledge already acquired concerning the number of the Elements, I offer the following obſervations.

By common experience, all men are aſſured that the matter which, in combination, renders bodies combuſtible, differs in many properties from that of water, and that the matter which chiefly conſtitutes the aerial atmoſphere, differs in many reſpects from that of earthy bodies; and that each of theſe different kinds of matter poſſeſſes ſome property peculiar to itſelf.

In the earlieſt ages, theſe four were adopted as elements by the moſt obſervant men, who uſed the word Fire to expreſs that part of compound combuſtible bodies, which we call Phlogiſton: and the modern Philoſophers, who are beſt acquainted with the compoſition of Bodies, are agreed in admitting an Earthy, an Aqueous, an Aerial, and Phlogiſtic Element, on various conſiderations; and eſpecially for this reaſon, that ſeveral compound bodies may be reſolved into portions conſiſting of Earthy Matter, or Water, or Air, or Phlogiſton; but theſe portions, however examined or divided into their ultimate parts, are found to conſiſt of atoms ſimilar to each other in every reſpect

In chemical analyſis we diſcover two other portions of matter, called Acid and Alkali: and I do not heſitate to rank theſe the number of Elements; becauſe the Acid or Alkaline matter, when ſeparated from bodies, forms an elaſtic inviſible fluid, which in all the experiments lately made, appears to admit of no decompoſition, and to be truly homogeneal ; and theſe fluids differ as much from each other, and from the elements already mentioned, as Water differs from Phlogiſton.

The properties wherein all theſe differ from each other, need not be enumerated, becauſe thoſe which are known to all Philoſophers, are ſufficient for our preſent purpoſe.

No one of theſe elements is to be rejected on the ſuppoſition that it is a compound formed of two or more of the others ; becauſe the ſeveral combinations of thoſe elements conſtitute known compounds; and becauſe portions of any of theſe elements poſſeſs the properties peculiar to ſuch elements reſpectively, in a more eminent degree, in proportion as theſe portions are more accurately ſeparated from every other kind of matter. This appears by comparing the acid elaſtic fluids, with acid diluted in water, or combined with any known matter; in comparing the alkaline elaſtic fluid with mild alkali, or alkali diluted, or alkali ſaturated; in the compariſon of moiſt or Phlogiſtic Air, with pure Air; and in a variety of other compariſons which will readily occur to the experienced chemiſt.

Light is a matter evidently different from the foregoing elements, and is to be added to the number of them; for it will hereafter appear, without any reference to what is ſaid in this place, that neither the priſmatic coloured ſpectrum, nor any other phenomenon hitherto obſerved, denotes Light to be a fluid conſiſting of parts diſſimilar in any reſpect.

Thus we reckon ſeven elements of matter; namely, Earth, Water, Air, Acid, Alkali, Phlogiſton, Light; the exiſtence and differences whereof, will further appear as we advance in the enſuing enquiries concerning the reciprocal relations of the parts of Matter.

Another, or perhaps many other elements, may be hereafter added to this liſt: but in the preſent ſtate of our knowledge, it ſeems more adviſeable to reſt on theſe only, than to reckon as many elements as there are portions of matter which have hitherto eluded the Art of Analyſis, and which in vulgar operations ſeem to be homogeneal. This opinion is derived from the following conſiderations.

Before the compoſition of Sulphur was diſcovered, Sulphur was conſidered as an homogeneal body; and the Philoſophers who imbibed this notion of the Chemiſts, were led thereby into many errors.

The Native Calcareous Earths, Gypſum, Fluors, and other Earthy bodies, were diſtinguiſhed as ſo many homogeneal maſſes, until the modern chemiſts had diſcovered that they are compounds.

The elaſtic inflammable fluid called Inflammable Air, was not reckoned amongſt the compound bodies, until the laſt winter, when we repeatedly compoſed and decompoſed it.

It was ſuſpected, many years ſince, that the ſeveral acids of the chemiſts, were compound bodies; but they were generally ſpoken of as homogeneal bodies, until lately that we have found each of them to be compoſed of acid matter aſſociated with other kinds of matter.

The like obſervations may be made concerning the ſeveral alkalies of the chemiſts, and v arious other bodies.

Theſe examples give us warning, that bodies are not to be held as homogeneal, merely becauſe we cannot yet ſeparate their heterogeneal parts; and ought to teach us, that all bodies which reſemble each other in one or more of thoſe properties which characterize an element, ought to be conſidered as compounds conſiſting chiefly of the matter of that element, and differing from it in ſome particulars, by reaſon of combination. And as all alkaline bodies are to be conſidered as ſeveral portions of the alkaline element predominant in ſeveral compounds;

and all acids bear the like relation to the acid element; and as Phlogiſtic or impure air bears the like relation to pure air; and as it is known that various liquors, whether fluid or congealed, bear the like relation to pure water or pure ice; and that all Phlogiſtic bodies have a ſimilar relation to the Phlogiſtic element: we have no ſatisfactory inſtance of the exiſtence of an element different from thoſe we have enumerated, unleſs certain Earthy Bodies, or Fire, or the Electric Fluid be offered as elements.

As the number of Earthy Bodies formerly accounted homogeneal, has gradually decreaſed as chemical knowledge advanced; and as all Earthy Bodies agree in many common characters; we ought rather to examine what compoſition or mode of aggregation conſtitutes the difference between the ſeveral Earthy Bodies, than preſume that Lime is an element different from Clay, and Clay an element different from Quartz, and

Quartz an element different from Talc; or that the ſeveral Metallic Earths are diſtinct elements.

In treating of Light, I ſhall endeavour to ſhew that Fire is not to be conſidered as an homogeneal body different from Light and Phlogiſton: And I am unwilling to admit the Electrical Fluid as an element different from theſe, until I find that ſuch an admiſſion is neceſſary towards our explaining the electrical phenomena.

By thus diſtinguiſhing and naming the elements, we ſhall avoid confuſion in ſpeaking of the reciprocal relations and actions of the parts of matter: By admitting fewer elements than thoſe which exiſt, our knowledge may be confined for a time, but it will be ſubſtantial: But if we had on the other hand miſtaken compounds for elements, or aſſumed elements, which are not demonſtrable; we muſt neceſſarily fall into the errors which ever flow from falſe principles.

The moſt weighty objections which may be oppoſed to theſe notions of the elements, will come under conſideration in the enſuing pages.

SECT. IV.

The Properties of ſolitary imperceptible Atoms are diſcoverable by Induction.

AS we are convinced by experience, that the whole weight of any body, is equalled by the ſum of the ſeveral weights of the ſmalleſt parts thereof which we can examine; and that the gravitation of any large body conſiſts of the gravitations of theſe parts; and as gravitation is never found to ceaſe, by reaſon of any further diviſion of maſſes; and as aerial and alkaline and other elaſtic fluids do gravitate when their ultimate parts are held diſtant from each other, as well as when theſe parts cohere and form ſolid ponderous bodies; it is reaſonably inferred that each atom of an heavy homogeneal maſs, doth gravitate according to the ſame law which regulates the gravitation of the maſs.

In a variety of chemical operations we learn that the attractive powers, whereby maſſes of earth or of acid and alkali, or of any other kind of matter, are combined or made to cohere, do operate to the ſame effect on the ſmalleſt viſible parts of theſe maſſes: and when the parts of ſolid bodies become inviſible in ſolutions, we find the ultimate inviſible parts are actuated by attractive powers, which cauſe them to unite and form viſible particles or large maſſes, in proportion as the menſtruum is withdrawn: and in the mixture of inviſible elaſtic fluids which condenſe each other, we perceive that theſe attractive powers actuate the ultimate parts of ſuch fluids, as well as the viſible parts of the maſſes which are formed of them: and thus we are authorized to conclude that each atom attracts according to the law which regulates the attraction of the body, conſiſting of any number of ſuch atoms; and that the law of attraction which is diſcoverable in a body which we can examine, is the law of attraction of the homogeneal atoms thereof, and of any one of theſe, which by reaſon of its minuteneſs we cannot examine.

By compreſſing fluids and meaſuring the ſpaces in which they are confined, and by reaſoning in the foregoing manner, we can aſcertain the repulſive powers of each inviſible atom of an Elaſtic Fluid.

The ſtate of an atom, with regard to motion or reſt, the *Inertia* and the Laws of Motion of an atom, are manifeſtly deducible from the ſtate and *Inertia* and the laws of motion of a body compoſed of ſuch atoms; and other properties and conditions of imperceptible atoms, are diſcoverable by induction from the experiments made on large bodies; and the method of induction will be further exemplified in the next ſection.

SECT. V.

The Atoms of Matter are immutable in Figure, and may, without ſenſible Error, be conſidered as globular Bodies.

WE learn from various experiments, that all hard bodies may without exception be rendered ſoft and fluid by a ſeparation of their parts, as flints are in liquor ſilicum, cryſtals in the jelly or liquor of cryſtal, and ſoluble ſtones, ſteel and platina and all metals in ſolutions; that the inviſible Elaſtic acid fluid contributes to the maſs and hardneſs of various ſtones, as alabaſter, fluor, all gypſeous ſpars, alum ſtone, and indeed almoſt all ſtones, as well as it contributes to the maſs and hardneſs of metallic and neutral ral ſalts and other ſubſtances; that the Alkaline inviſible Elaſtic fluid in like manner contributes to the maſs and hardneſs of bones, ivory, various animal and vegetable ſubſtances, many mineral hard bodies, and neutral ſalts; that Atmoſpheric Air is reducible into ſolid maſſes, by the mediation of other matter; that water becomes ſolid when it is ſufficiently cooled, or when it is combined in ſalts, ſtones and other compound bodies; that the ſubtil Elaſtic inflammable principle called Phlogiſton, hath the like condition in the maſs of inflammable bodies: and finally, that, without experimental exception, theſe fine fluids when their parts are ſufficiently approximated from hard bodies.

A ſtone or metallic glaſs conſiſting of ſuch atoms is diaphanous and porous; its contiguous atoms therefore can touch each other only in a few points; and as theſe ſtones in the baſe of a lofty tower, or in any other ſituation, preſſed with immenſe force, are not found to yield ſenſibly; and as all hard bodies ſuſtain the greateſt known forces tending to compreſs them, without any diminution of their bulk, except what may happen in the approximation of their parts by their cooling or our counteracting the effects of fire; it appears that each atom of any Element can ſuſtain the greateſt known force impreſſed on a few points of it, without bending into the void ſpaces in the compreſſed bodies, or being altered in its figure; and that in phyſical reaſoning every atom is to be accounted immutable in figure as well as indiviſible.

Sir *Iſacc Newton* reaſons to this effect in the illuſtration of his Third Rule prefixed to the third book of his Principia Math. And in the thirty-firſt Query annexed to his Optics, page 364 of the ſecond edition, he ſays, "All bodies ſeem to be compoſed of hard "particles: for otherwiſe fluids would not "congeal; as water, oils, vinegar, and ſpi"rit or oil of vitriol do by freezing; mer"cury by fumes of lead; ſpirit of nitre and "mercury, by diſſolving the mercury and "evaporating the flegm; ſpirit of wine and "ſpirit of urine, by deflegming and mixing "them; and ſpirit of urine and ſpirit of ſalt, "by ſubliming them together to make ſal"armoniac. Even the rays of light ſeem to "be hard bodies; for otherwiſe they would "not retain different properties in their dif"ferent ſides. And therefore hardneſs may "be reckoned the property of all uncom"pounded matter. At leaſt, this ſeems to be "as evident as the univerſal impenetrability "of matter. For all bodies, ſo far as expe-

"rience reaches, are either hard, or may be "hardened; and we have no other evidence "of univerſal impenetrability, beſides a large "experience without an experimental excep"tion. Now if compound bodies are ſo very "hard as we find ſome of them to be, and "yet are very porous, and conſiſt of parts "which are only laid together; the ſimple "particles which are void of pores, and "were never yet divided, muſt be much "harder."

Foraſmuch as ſolid bodies are found capable of receiving a conſiderable quantity of groſs matter into their void ſpaces, and yet remain pervious to the ſubtil matter of Light or the Electric fluid; and as all bodies, whatever the matter thereof may be, and however compounded, contain ſpaces void of their matter; and as no other, except a figure of the atoms approaching nearly to the globular form, can maintain ſuch univerſal poroſity of bodies, and ſo much ſpace as we find in them void of their matter, we may, without ſenſible error, conſider and repreſent the atoms as globular bodies.

SECT. VI.

The Numerous Properties of Compound Bodies, depend on the Properties of their Heterogeneal Parts.

WHEN we blend together ſeveral portions of Air, or of Water, or of Acid or Alkali, or of any homegeneal body, we are convinced that the multiplication or the juxtapoſition of ſimilar parts cannot cauſe a change in the properties of the maſs: But in every poſſible mixture of heterogeneal bodies, we find the compound to have properties different from thoſe of the bodies which were mixed. Theſe differences are obvious when we compare ſal-ammoniac with the elaſtic acid and alkaline fluids with which we compoſe it; or when we compare a metal with its earth, or ſuphur with its acid, or an earthy ſalt with the earth and acid whereof it was formed; and are eaſily diſcoverable in all known compounds, whether ſolid, or fluid, or Elaſtic and fluid like air.

As the powers which cauſe the ſtronger and weaker attractions and the various elections, and the divers repulſions of different parts of matter, and the relations of theſe parts to each other, muſt be compounded in compound bodies; whether we expreſs the powers or their effects by the word Properties, the properties of compound bodies muſt, for this reaſon only, be different from thoſe of their homogeneal parts: and foraſmuch as the properties of compound bodies are found to differ more or leſs from thoſe of either of the homogeneal bodies of which they are compoſed, according to the partial or total coincidence or counteraction of the powers wherewith the homogeneal bodies are endued or actuated; and as theſe Phenomena of Combination are explicable according to theſe notions of the compoſition of theſe powers; no other cauſe of theſe Phenomena is to be aſſumed; and the Properties of Compound Bodies depend on the properties of their heterogeneal parts.

This will more clearly appear as we proceed to conſider the properties of matter, and to ſhew that the powers implanted in the atoms thereof are never commuted or deſtroyed. For if the powers which actuate the parts of matter are inceſſant and immutable, the properties of a compound can differ from thoſe of an element, only by reaſon of the compoſition of theſe powers

SECT. VII.

Bodies are not mutable into each other, and the Properties of the Atoms of any Element are indefeaſible.

LEST the forgoing notions relative to the Elements and their ultimate parts ſhould be neglected through prejudice, or haſtily condemned; and to obviate certain objections which might interrupt us in our enquiries concerning Light; I muſt take notice of an opinion which has been formerly entertained by ſome Philoſophers, and is prevalent at this time.

Sir *Iſaac Newton*, in the thirty-firſt Query already cited, ſays,

> " Now the ſmalleſt particles of matter
> " may cohere by the ſtrongeſt attractions,
> " and compoſe bigger particles of weaker
> " virtue; and many of theſe may cohere
> " and compoſe bigger particles whoſe vir-
> " tue is ſtill weaker, and ſo on for divers
> " ſucceſſions, until the progreſſion end in
> " the biggeſt particles on which the ope-
> " rations in Chemiſtry, and the colours of
> " natural bodies depend, and which by
> " cohering compoſe bodies of a ſenſible
> " magnitude, &c."

Much ſtreſs is laid on this and the ſubſequent paſſage by thoſe who imagine, that the ſmalleſt Phyſical parts of matter differ from each other in no reſpect; that by the union of two or more of theſe, particles are formed poſſeſſing different properties, according to the number and arrangement of their parts; that ſuch particles as are compoſed of the ſame number of parts, conſtitute the portions of matter which I call Elements; and that particles conſiſting of unequal numbers of parts, and differing in magnitude and figure, compoſe the bodies called Compounds.

The hypotheſis is framed to accord with experiments which are thought to indicate the converſion of any one of our Elements into another, and anſwers no end except that of enabling us to acquieſce in our ignorance of the proceſſes of Nature: For according to the hypotheſis, nothing more is requiſite towards ſuch a converſion, than a proceſs wherein the ultimate parts of a body may be made to aſſume new arrangements and to form larger or ſmaller particles.

In combuſtions, certain bodies, as charcoal, fats, oils, bitumens, reſins, ſulphur, ſeem to be, for the greater part, converted into Fire and Light. And Æthers and eſſential oils and Alkohol ſeem to be almoſt totally changed in like manner.

When a conſiderable part of the ſubſtance of earthy and other bodies, is made to aſſume the form of an Elaſtic inviſible fluid in ſolutions, fermentations, putrefactions, or by ignition; and when certain ſaline bodies are found totally reducible to this condition; and when all ſuch fluids are called Air; This in the relation, implies a converſion of the bodies into Air; But when theſe fluids are diſtinguiſhed from Air, ſtill there ſeems to be an approximation towards ſuch a change.

The growth of vegetables in Air and water only, has been offered as a proof of the change of air and water, into the earthy, Acid, alkaline and inflammable matter of the enlarged plant.

When Air is obtained in conſiderable quantity from earthy bodies, particularly metallic calces, this is taken by ſome men as a change of earthy matter into air.

The earth obtained in repeated diſtillations, or long continued digeſtions of water, has been thought to indicate the converſion of water into earth.

When certain fluids, ſuch as ſaturated ſolutions of earths, are mixed with alkaline liquors, or expoſed to the Elaſtic alkaline fluid, and form therewith ſolid ponderous maſſes like thoſe of the purer earths: and when the like event attends the expoſure of Liquamen Silicum to acid vapours: and when the prepared powder of plaiſter ſtone is mingled with water, and when the liquid mixture ſuffered to reſt, preſently becomes ſolid without loſs of weight; theſe may be repreſented as converſions of Water and other matter into Earth: and twelve months are ſcarcely elapſed ſince the experiments of the Swediſh Chemiſt who diſcovered the Fluor Acid, have been exhibited with ſuch artifice as to make many ſenſible men believe that a ſort of air detached from fluors converts water into ſtone.

It would lead me away too far from the chief objects of this Eſſay, if I were to deſcribe ſeverally all the ſubjects of theſe ſummary Obſervations, and then ſhew the cauſes of the foregoing deceptions, and the real event of every operation, wherein bodies *ſtem* to be commuted. I muſt therefore content myſelf with offering the following remarks on theſe ſubjects.

The proceſſes lately mentioned or alluded to, being repeated in the preſence of the gentlemen to whom this Volume is addreſſed; we found the ſources of the foregoing deceptions, but could not perceive any ground whereon the opinion concerning the convertibility of our Elements can be defended henceforward.

Thoſe who are acquainted with the diſcoveries lately made concerning Phlogiſton, and who know that it is an ingredient in all inflammable bodies, and is neceſſary towards the combuſtion of bodies, and towards the formation of the Fire which appears during the combuſtion of them; but who nevertheleſs imagine that Phlogiſton when detached from other matter, is Fire; will readily allow that in combuſtions there is no converſion of bodies into Fire, but that a portion of them which is really Fire, being ſet at liberty, appears and acts as Fire.

But as we find Phlogiſton to differ from Fire, as much as Elements do from compounds, and as we are certain that Phlogiſton is a conſtituent part of that ſort of Fire which is formed in combuſtions, ſolutions and the proceſſes related; we perceive that the Phlogiſtic matter of bodies contributes to the compoſition of fire, and that no other matter of bodies is converted into fire.

No one of the inſtances wherein Elaſtic fluids are produced from bodies, truly indicates a converſion of Our Elements. For when theſe fluids differ from Air, they are found to conſiſt of Acid, or Alkali, or to be compounded of one of theſe and Phlogiſton, or of Phlogiſton and Air; and as the Elaſtic fluid called *Fixable Air*, when detached from Chalk, is now allowed not to denote the converſion of Chalk into Fixable Air; and as this elaſtic fluid when combined with Lime forms Chalk, and thus appears to be a component part of Chalk, and to be different from Lime, whether combined with it or not; ſo all other elaſtic fluids detached from compound bodies, indicate the compoſition of theſe bodies, but not the converſion of them : and there is no more reaſon for imagining that a ſolid body is in a ſtate of approximation towards this converſion, when it becomes an Elaſtic fluid, than there is to ſuppoſe that two bodies are homogeneal or alike in all reſpects, when they have one common property.

Various experiments have convinced us that the matter of Vegetables, not excepting Earth, is contained in Atmoſpheric Air, partly blended intimately, partly wafted therein ; and whilſt we have this ſource of nouriſhment, we need not rack invention to conceive how a plant can convert Air into Earth, Acid, Alkali, Phlogiſton, which with Water are the principles of vegetating bodies.

With reſpect to the ſubſtances from which atmoſpheric or pure Air may be diſengaged ; we know from Experiment that they attract air, and acquire encreaſe of weight thereby, and that after they have been diveſted of Air, they will attract it again and unite with it, in the ſame circumſtances wherein they firſt acquired Air : and all theſe experiments ſhew the elective attractions of Air, but nothing like converſion.

In repeating the experiments offered to prove the change of Water into Earth, and after making others leſs exceptionable, we learn that Water is not deprived of Earthy matter in one diſtillation ; becauſe ſaline matter, which is not thus ſeparable, aſſiſts in carrying Earthy matter into the recipient ; but eſpecially becauſe the moſt fixed bodies are carried over in diſtillations, by mere impulſe received from the riſing vapours or diſengaged elaſtic fluids : we find that when water is diſtilled in veſſels joined by lute, ſome of the lute will mix with the Water, whilſt ſome of the Water tranſpires ; and that metallic veſſels contribute greatly and quickly to the Earthy matter left in repeated diſtillations ; we likewiſe perceive that Water in motion and in contract with glaſs veſſels, in diſtillation, cauſes a conſiderable abraſion, ſuch as happens to the hardeſt ſtones which are expoſed to ſtreams or dripping of Water, or as might be expected from the joint operation of friction and attraction, ſince water attracts glaſs with conſiderable force. But finding after two hundred diſtillations in proper veſſels, that much Earthy matter appeared, and yet the quantity and quality of the Water were unaltered, we are aſſured that Water is not convertible into Earth or any other body by diſtillation: and further we find, that nine months expoſure of Water to the Sun, produces no alteration in the Water, provided it has been previouſly diſtilled in new glaſs veſſels, and then expoſed in a freſh and clean mattraſs, into which no oily vapour is ſuffered to enter during the ſealing of it hermetically. It is therefore repugnant to experience to preſume that Water is convertible into Earth or any thing elſe that has been mentioned as the product of thoſe proceſſes.

The moſt reſpectable writers truly affirm that they obtained a conſiderable quantity of Earth, by repeated diſtillations of Water; and a gentleman whoſe veracity is unqueſtionable has lately ſhewn to ſeveral of his friends a quantity of Earth "*obtained in the* "*diſtillations of an equal weight of Water*:" but this fact has been miſrepreſented by a late writer, who ſays that the "*Water had been* "*converted into Earth, weight for weight.*"

With reſpect to the conſiſtent maſſes formed in conſequence of the mixture of the ſolutions and fluids already inſtanced, or of the mixture of gypſeous powders with water, it is ſufficient to obſerve that the water of theſe mixtures is combined in the maſſes, or held therein by capillary attraction; and that we are aſſured by ſeveral experiments wherein the Water is expelled from theſe bodies, and recoverable to its former condition, that no part of the Water has been converted into Earth in conſequence of ſuch mixtures.

When the elaſtic compound called Fluor acid, is received in Water, the Acid unites with the Water and depoſites the earthy matter which is evidently a component part of this acidulous fluid; in the ſame manner as Earth of Antimony is a component part of the volatile butter of Antimony, which is decompoſed in Water, and as Arſenic is a component part of the Butter of Arſenic, which ſmoaks and exhales in the Air, without being heated. The Water thus charged with the earthy matter of the fluor acid, forms with that Earth diffuſed in it, a gelati- or a more ſolid maſs, ſuch as we form with aluminous or ſiliceous Earth diffuſed in the like manner; but it is ſeparable from the Earth by diſtillation, and undergoes no converſion.

As no one of the phenomena hitherto obſerved truly indicates a converſion of our elements, or a tranſlation of the properties of any parts of one element to parts of another element, the hypotheſis, framed in ſubſervience to theſe imaginary converſions, is uſeleſs. It is moreover improbable, for the following reaſons.

As the union of homogeneal parts of earth or of water, or the juxta poſition of homogeneal parts of air or of acid or of alkali, doth not alter the properties of theſe as was formerly obſerved; we cannot even by analogy preſume that particles, formed of a greater or ſmaller number of the ſuppoſed ultimate homogeneal parts, can, by reaſon of the different ſize or figure of theſe particles, differ from each other, in their relations or properties, ſo much as we find the *Repellent* parts of air or of acid or of alkali, to differ from the *Attractive* parts of earth or of water, or ſo much as the parts of any one of our elements are found to differ from the parts of any other element, in their attractions and the forces and elections thereof. And the futility of the hypotheſis will be ſtill more apparent when we recount ſome of the experiments, which ſhew that the parts of bodies, which attract each other in the contact of them, do attract at all diſtances between them; and that the parts, which repel reciprocally when they are moſt nearly approximated, do repelat every diſtance between them: for according to theſe Laws, the particles of matter, if they were formed of homogeneal ultimate parts in conformity to the hypotheſis, ought all to attract, or all to repel each other, whatever be the number of their ſuppoſed ultimate parts, and whatever be their figure.

Since we are not authorized by any obſervation, or induced by any expediency, to ſuppoſe that the parts of our elements can exchange their properties or be commuted: and ſince the ſmalleſt phyſical parts of bodies appear, after numerous combinations and decompoſitions, and in all operations, to preſerve their diſtinguiſhing characters inviolated, altho' the effects of the powers which actuate them are varied during the compoſition or counter action of theſe powers; we are bound by the rules of phyſical reaſoning to conclude, that bodies or elements are not commutable, and that the implanted powers or properties of the atoms of any element are indefeaſible.

I know not any doctrine ſo injurious to the cauſe of natural philoſophy, as that, of the converſion of bodies; for it diverts men from the examination of what really happens to bodies in many intereſting operations; and it ſtops all enquiry into the properties of the ultimate parts of matter; which enquiry is the moſt important of all that can engage a modern philoſopher.

As it is my purpoſe rather to explain and recommend, than to enforce theſe notions concerning the parts and properties of matter, I omit a great number of obſervations, which might be offered in confirmation of them; and preſuming that my readers will collect, from the following ſections, ſeveral arguments to this effect, I ſhall conclude this part with the following remarks.

As nothing leſs than a ſupernatural agent can annihilate matter that is once created, ſo nothing leſs can make the parts of air to attract each other as the parts of earth or of water do; or can withdraw from any parts of matter the properties or powers once aſſigned to them; or can cauſe the heterogeneal parts to exchange their properties: and as all the parts of the known ſyſtem appear, ſo far as we can diſcern, to be governed by inceſſant and immutable laws, and to be framed with ſo much preſcience and wiſdom that they require no new alterations regulations or ſubſtitutions of them; we ought to conduct our enquiries concerning natural bodies, by this rule; that the figure, or ſize, or property of an atom at any one time, is the figure and ſize, and property of the ſame at all times;

and

and that the powers which cauſe the relations of matter, act inceſſantly; and that moſt of the varieties obſervable in bodies, depend on the compoſition and counteraction of theſe powers, during the combination of diſſimilar parts of matter.

What I have thus ſaid of matter in general, is neceſſarily applicable to Light; which we ſhall find to be affected by powers analogous to thoſe of other matter, and to be variouſly modified thereby, but never to be converted into a different kind of matter. And they miſtake the meaning of the illuſtrious *Newton*, who quote the thirtieth Query in his Optics, and ſome Paſſages of his *Syſtema Mundi*, as evidence for the converſion of Light and Bodies. The 30th Query is this:

" *Qu.* 30. Are not groſs Bodies and Light
" convertible into one another, and may not
" Bodies receive much of their activity from
" the particles of Light which enter their
" compoſition? For all fixed bodies being
" heated emit Light ſo long as they continue
" ſufficiently hot, and Light naturally ſtops

" in bodies as often as its rays ſtrike upon " their parts, as we ſhew'd above. I know " no body leſs apt to ſhine than water; and " yet water by frequent diſtillations changes " into fixed earth, as Mr. *Boyle* has tried; " and then this earth being enabled to endure a ſufficient heat, ſhines by heat like " other bodies.

" The changing of bodies into Light, and " Light into bodies, is very conformable to " the courſe of nature, which ſeems delighted with tranſmutations. Water, which " is a very fluid taſtleſs ſalt, ſhe changes by " heat into vapour, which is a ſort of air, " and by cold into ice, which is a hard, " pellucid, brittle, fuſible ſtone: and this " ſtone returns into water by heat, and vapour returns into water by cold. Earth " by heat becomes Fire, and by cold returns " into earth. Denſe bodies by fermentation " rarify into ſeveral ſorts of air, and this air " by fermentation, and ſometimes without " it, returns into denſe bodies. Mercury " appears ſometimes in the form of a fluid " metal, ſometimes in the form of hard brit-

“ tle metal, ſometimes in the form of a corroſive
“ pellucid ſalt called ſublimate ; ſometimes
“ in the form of a taſtleſs, pellucid, volatile
“ white earth, called *Mercurius dulcis*; or
“ in that of a red opake volatile earth, called
“ cinnaber ; or in that of a red or white precipitate,
“ or in that of a fluid ſalt; and
“ in diſtillation it turns into vapour, and
“ being agitated *in vacuo*, it ſhines like Fire.
“ And after all theſe changes it returns again
“ into its firſt form of mercury. Eggs grow
“ from inſenſible magnitudes, and change
“ into animals ; tadpoles into frogs ; and
“ worms into flies. All birds, beaſts and
“ fiſhes, inſects, trees, and other vegetables,
“ with their ſeveral parts, grow out of water
“ and watry tinctures and ſalts, and by putrefaction
“ return again into watry ſubſtances.
“ And water ſtanding a few days in
“ the open air, yields a tincture, which (like
“ that of mault) by ſtanding longer yields a
“ ſediment and a ſpirit, but before putrefaction
“ is fit nouriſhment for animals and vegetables.
“ And among ſuch various and
“ ſtrange tranſmutations, why may not na-

" ture change bodies into Light, and Light
" into bodies?"

The paſſage in his Principia which ſtrikes moſt to this effect, is the following, taken from page 515 of the Third Edition.

" Caudæ igitur, quæ in cometarum perihelii naſcuntur, in regiones longinquas
" cum eorum capitibus abibunt, & vel inde
" poſt longam annorum ſeriem cum iiſdem ad
" nos redibunt, vel potius ibi rarefactæ paulatim
" evaneſcent. Nam poſtea in deſcenſu
" capitum ad ſolem caudæ novæ breviuſculæ
" lento motu a capitibus propagari debebunt,
" & ſubinde in periheliis cometarum illorum,
" qui ad uſque atmoſphæram ſolis deſcendunt,
" in immenſum augeri. Vapor enim
" in ſpatiis illis liberrimis perpetuo rareſcit ac
" dilatatur. Qua ratione ſit ut cauda omnis
" ad extremitatem ſuperiorem latior ſit quam
" juxta caput cometæ. Ea autem rarefactione
" vaporem perpetuo dilatatum diffundi
" tandem & ſpargi per cælos univerſos, deinde
" paulatim in planetas per gravitatem
" ſuam attrahi, & cum eorum atmoſphæris

“ miſceri rationi conſentaneum videtur. Nam
“ quemadmodum maria ad conſtitutionem
“ terræ hujus omnino requiruntur, idque ut
“ ex iis per calorem ſolis vapores copioſe ſa-
“ tis excitentur, qui vel in nubes coacti de-
“ cidant in pluviis, & terram omnem ad pro-
“ creationem vegetabilum irrigent et nutri-
“ ant ; vel in frigidis montium verticibus
“ condenſati (ut aliqui cum ratione philoſo-
“ phantur) decurrant in fontes & flumina :
“ ſic ad conſervationem marium & humorum
“ in planetis requiri videntur cometæ, ex
“ quorum exhalationibus & vaporibus con-
“ denſatis, quicquid liquoris per vegetatio-
“ nem & putrefactionem conſumitur & in
“ terram aridam convertitur, continuo ſup-
“ pleri & refici poſſit. Nam vegetabilia om-
“ nia ex liquoribus omnino creſcunt, dein
“ magna ex parte in terram aridam per pu-
“ trefactionem abeunt, & limus ex liquori-
“ bus putrefactis perpetuo decidit. Hinc
“ moles terræ aridæ indies augetur, & liquo-
“ res, niſi aliunde augmentum ſumerent,
“ perpetuo decreſcere deberent, ac tandem
“ deficere. Porro ſuſpicor ſpiritum illum,
“ qui aëris noſtri pars minima eſt ſed ſubti-

“ liſſima

" lliſſima & optima, & ad rerum omnium
" vitam requiritur, ex cometis precipue ve-
" nire."

Previous to the Queries annexed to his Optics, he ſays, that he propoſes them "*In* " *order to a farther ſearch to be made by others*;" and the paſſage taken from his *Syſtema Mundi*, is by him introduced as a conjecture. In this view, theſe ſentences do not appear unworthy of him, eſpecially when we conſider the time in which he wrote; But they are not to be held forth as his doctrines, or oppoſed to the growing experience of mankind.

SECT. VIII.

The Effects called Attraction and Repulſion are not to be aſcribed to the Agency of any imagined Ethereal Fluid: Neither is an Ethereal Fluid to be aſſumed in optical reaſoning.

HITHERTO I have uſed the words Attraction and Repulſion in Sir *Iſaac Newton's* ſenſe of them, without attempting to define the cauſes or powers which produce the well known effects expreſſed by theſe Terms. But henceforward it will be neſſary to extend our views beyond theſe effects, even to the powers themſelves; which we conceive to exiſt in full force in many inſtances, without producing any ſenſible effect, becauſe they counteract each other.

Sir *Iſaac Newton's* conjectures concerning theſe may be gathered from the following paſſages.

In the eighteenth, nineteenth, and twentyeth Queries in the ſecond edition of his Optics, he mentions the reaſons which incline him to preſume that various phenomena of fire and Light are produced by the mediation of a ſubtil elaſtic fluid, which he calls Ether, or the athereal medium; then follows the twenty-firſt Query in theſe words.

" Is not this medium much rarer within
" the denſe bodies of the ſun, ſtars, planets
" and comets, than in the empty celeſtial ſpaces between them? and in paſſing from
" them to great diſtances, doth it not grow
" denſer and denſer perpetually, and thereby
" cauſe the gravity of thoſe great bodies towards one another, *and of their parts towards*
" *the bodies*; every body endeavouring to go
" from the denſer parts of the medium towards the rarer? for if this medium be
" rarer within the ſun's body, than at its ſurface, and rarer there than at the hundredth
" part of an inch from its body, and rarer
" there than at the fiftieth part of an inch
" from its body, and rarer there than at the
" orb of *Saturn*; I ſee no reaſon why the in-

" creaſe of denſity ſhould ſtop any where, " and not rather be continued thro all diſ- " tances from the ſun to *Saturn*, and beyond. " And though this increaſe of denſity may " at great diſtances be exceeding ſlow, yet if " the elaſtic force of this medium be exceed- " ing great, it may ſuffice to impel bodies " from the denſer parts of the medium to- " wards the rarer, with all that power which " we call gravity." *&c.*———

Again in the thirty-firſt Query he ſays; " For it well known that bodies act upon " one another by the attractions of Gravity, " Magnetiſm and Electricity; and theſe in- " ſtances ſhew the tenor and courſe of Na- " ture, and make it not improbable but that " there may be more attractive powers than " theſe. For Nature is very conſonant and " conformable to herſelf. How theſe at- " tractions may be performed, I do not here " conſider. What I call attraction *may be* " *performed by impulſe*, or by ſome other means " unknown to me. I uſe that word here to " ſignify only in general any force by which

" bodies tend towards one another, whatſo-
" ever be the cauſe."

Laſtly, in the thirty-firſt Query, after reciting inſtances of elective attractions, capillary attraction, coheſion, aggregation; and after ſuggeſting polarity in the particles of ſalts and of the iſland cryſtal, he gives the following paragraphs, which I ſelect as relating moſt immediately to my preſent purpoſe.

Page 365. " And how ſuch very hard
" particles which are only laid together,
" and touch only in a few points, can ſtick
" together, and that ſo firmly as they do,
" without the aſſiſtance of ſomething which
" cauſes them to be attracted or preſſed to-
" wards one another, is very difficult to con-
" ceive."

Page 369. " There are therefore agents
" in Nature able to make the particles of bo-
" dies ſtick together by very ſtrong attrac-
" tions. And it is the buſineſs of experi-
" mental Philoſophy to find them out."

Page 372. "And thus Nature will be very
" conformable to herſelf and very ſimple,
" performing all the great motions of the
" heavenly bodies by the attraction of gravity
" which intercedes thoſe bodies, and
" almoſt all the ſmall ones of their particles
" by ſome other attractive and repelling
" powers which intercede the particles."

In Page 376, he ſpeaks of the indeſtructibility of the particles of matter, and proceeds thus, "It ſeems to me farther, that theſe
" particles have not only a *vis inertiæ*, accompanied
" with ſuch paſſive laws of motion
" as naturally reſult from that force,
" but alſo that they are moved by certain
" active principles, ſuch as is that of
" gravity, and that which cauſes fermentation,
" and the coheſion of bodies. Theſe
" principles I conſider not as occult qualities,
" ſuppoſed to reſult from the ſpecific
" forms of things, but *as general laws of*
" *Nature, by which the things themſelves are*
" *formed*: their truth appearing to us by
" phenomena, though their cauſes be not
" yet diſcovered."

In the advertiſement prefixed to his ſecond edition of his Optics, he ſays, "And to "ſhew that I do not take gravity for an "eſſential property of bodies, I have added "one queſtion concerning its cauſe, chuſing "to propoſe it by way of a queſtion, be- "cauſe I am not yet ſatisfied about it for "for want of experiments."

And we read in the Schol. of Prop. 69, of the firſt book of his *Prin. Math.*—"Vocem "attractionis hic generaliter uſurpo pro cor- "porum conatu quocunque accedendi ad in- "vicem: ſive conatus iſte fiat ab actione cor- "porum, vel ſe mutuo petentium, ſel per ſpi- "ritus emiſſos ſe invicem agitantium; ſive is "ab actionæ ætheris, aut aeris, mediive cu- "juſcunque ſeu corporei ſeu incorporei ori- "atur corpora innatantia in ſe invicem ut- "cunque impellentis."

And in the laſt page of the ſame work he writes, "Hactenus phænomena cælorum & "maris noſtri per vim gravitatis expoſui, "ſed cauſam gravitatis nondum aſſignavi

" Oritur utique hæc vis a cauſa aliqua;
" quæ penetrat ad uſque centra ſolis &
" planetarum, ſine virtutis diminutione;
" quæqua agit non pro quantitate *ſuperficierum*
" particularum, in quas agit (ut ſolent cauſæ
" mechanicæ) ſed pro quantitate materiæ *ſolidæ*;
" & cujus actio in immenſas diſtantias
" undique extenditur, decreſcendo ſemper in
" duplicata ratione diſtantiarum. Gravitas
" in ſolem componitur ex gravitatibus in ſingulas
" ſolis particulas, & recedendo a ſole
" decreſcit accurate in duplicata ratione diſtantiarum
" ad uſque orbem Saturni, ut ex
" quiete apheliorum planetarum manifeſtum
" eſt, & ad uſque ultima cometarum aphelia,
" ſimodo aphelia illa quieſcant. Rationem
" vero harum gravitatis proprietatum ex phænomenis
" nondum potui deducere, & hypotheſes
" non fingo.

" Adjicere jam liceret nonnulla de ſpiritu
" quodam ſubtiliſſimo corpora craſſa pervadente,
" & in iiſdem latente; cujus vi & actionibus
" particulæ corporum ad minimas
" diſtantias ſe mutuo attrahunt, & contiguæ

“ factæ cohærent; & corpora electrica agunt ad diſtantias majores, tam repellendo quam attrahendo corpuſcula vicinia; & lux emittitur, reflectitur, refringitur, inflectitur, & corpora calefacit; & ſenſatio omnis excitatur, & membra animalium ad voluntatem moventur, vibrationibus ſcilicet hujus ſpiritus per ſolida nervorum capillamenta ab externis ſenſuum organis ad cerebrum & a cerebro in muſculos propagatis. Sed hæc paucis exponi non poſſunt; neque adeſt ſufficiens copia experimentorum, quibus leges actionum hujus ſpiritus accurate determinari & monſtrari debent.”

Hence it appears that *Newton* propoſed no ſettled opinions on this ſubject; but he adviſes us to enquire whether a material agent be the immediate cauſe of attraction and repulſion, and whether there be in nature many ſuch agents effecting the ſeveral repulſions and attractions which we diſtinguiſh.

What this chaſte philoſopher offers in this manner, others have aſſumed as *data*, and on ſuch grounds have built ſyſtems, the particulars whereof I paſs unnoticed, attending only to the fundamental parts, which are an ethereal fluid or divers ethereal fluids aſſumed as the agent or agents by which bodies are made to attract or repel each other, and by which Rays of Light are reflected refracted and inflectd.

However different the notions of men may be, concerning the cauſe of attraction or repulſion, all who are ſufficiently informed by experience, muſt agree in admitting the following poſitions expreſſing only their common ſenſe of things and facts.

The ſmalleſt known parts or the bigger portions of matter do not all attract each other: the ſmalleſt known parts or the bigger portions of matter do not all repell each other: and the bodies which attract each other, do not all attract with equal force, or with forces which are directly as their quantities of matter. Thoſe who are unacquainted with the particular inſtances comprehended in theſe general poſitions, may eaſily collect them from the following ſections, where they will be pointed out and illuſtrated, with a view towards our theory of attraction, and towards the foregoing notions.

Now if we ſuppoſe that one ethereal element or fluid does produce, on the ſmalleſt known parts and on the bigger portions of different bodies, effects ſo different from each other as attraction is from repulſion: If, for inſtance, it be ſuppoſed that one ethereal fluid doth cauſe the parts of acid to recede from each other with great force, and the parts of alkali to recede from each other with the like force; and that it doth nevertheleſs cauſe the parts of acid to approach and adhere to the parts of alkli with conſiderable force; we muſt conclude that this ethereal fluid acts, not by mere impulſe, but by election; and that it hath different relations to different parts of matter, whether theſe parts be ultimate parts or particles: And when we further conſider the many different elective repulſions and elective attractions already diſcovered; we muſt conclude that the relations of the ſuppoſed ether, to different parts of matter, are different and numerous.

As Ether is matter; relative properties and elective relations widely differing from each other, are according to the hypotheſis attributed to different parts of matter: and as the ſuppoſed effects of the ether are preciſely thoſe which may, in a manner much more conſiſtent with our ſenſe of them, and with the ſimplicity of nature, be produced by innate powers or virtues of the very parts which viſibly attract or repell each other; the hypotheſis is uſeleſs. But ſince we have no proof of the exiſtence of an ethereal fluid different from the fluids which we expreſs by other names, and which are the ſubjects and not the cauſe of attraction or repulſion; and ſince it is highly improbable that any one kind of matter hath ſo many different relations to different parts which we call elements, and that theſe parts have no ſuch relations to each other; and ſince the hypotheſis of an Ether is uſeleſs; the Ether was aſſumed without reaſon or neceſſity, and is to be rejected.

By the like argument, deduced from the different elective repulſions, and the different elective attractions, we may conclude, that an Ether is not the cauſe of attractions only, when all the other parts of matter are ſuppoſed to repell each other; and that an Ether is not the cauſe of repulſions only, when all the other parts of matter are ſuppoſed to be endued with a property of approaching and adhering to each other.

But if we ſuppoſe that the phenomena of attraction and repulſion are cauſed by different ethereal Fluids; we muſt, for the reaſons already mentioned, conclude that there are many ethereal elements or fluids, differing each from the other and from the electric fluid; of which elements not one can be demonſtrated. This hypotheſis therefore is unphiloſophic.

As the parts of Air and thoſe of Acid and thoſe of Alkali and thoſe of other elements, repell each other, and at the ſame time attract ſeveral bodies different from themſelves, there is nothing ſingular in the electric fluid, which ought to induce us to conclude that it is the cauſe of attraction or of repulſion : on the contrary the Electrical Phenomena ſhew that it is influenced by powers of attraction and repulſion, as other elaſtic fluids are. For when the electric fluid follows ſome bodies in preference to others, and when it is drawn by ſome bodies more forcibly than by others, and when it draws light bodies to the coaſt where it is accumulated and held ; this is nothing more than elective attractions of this fluid to the bodies ; and it is analogous to the elective attractions of every element and compound. And as many ſorts of matter which contribute to the maſs of groſs ſolid ponderous bodies, do form elaſtic inviſible fluids, when the repulſive virtues of their parts are not overpowered by the attractive forces of any interpoſed matter ; it is not ſingular that the more ſubtil electrical matter ſhould form a ſubtil, elaſtic, inviſible fluid ; and that bodies encompaſſed with ſmall and equally denſe atmoſpheres of this repellent matter, ſhould *ſeem* to repel each other, whilſt their atmoſpheres really repel each other : for as the bodies attract their reſpective atmoſpheres, whilſt the atmoſpheres repell each other, the bodies ought to recede from each other by reaſon of their atmoſpheres.

The electric fluid being a ſubject on which the power of attraction is exerciſed, and a ſubject in which we diſcover elective attractions analogous to thoſe of other matter, can no more be the cauſe of the attractions of other bodies than Air is the cauſe by which Acid attracts Alkali, or Water, or metallic ſubſtances.

It is moreover to be conſidered that the ſame bodies which ruſh together contrary to their gravitation, when they are unequally charged with electric matter, do repel each other, when their charges are made equal by the acceſſion of more electric matter; and that if the electric fluid be the cauſe and not the ſubject of theſe attractions and repulſions, the ſame cauſe or power being encreaſed does not produce a greater effect, but two oppoſite effects on the ſame bodies; which is repugnant to reaſon. Wherefore the electric fluid is like all other fluids, a ſubject of attraction, but not the cauſe thereof: and for the like reaſon it is not the cauſe of repulſion.

Now ſince the aſſumption of one or many etherial fluids anſwers no purpoſe in Natural Philoſophy, except to place an imaginary ſtep between the power of attraction and the will of the Divinity; and as the ether is not demonſtrable; and as it is inconſiſtent with the tenour of nature to imagine that many inſtruments are employed towards producing effects for which a few may ſuffice; we may reaſonably conclude, that there is no etherial fluid different from the fluids which we expreſs by other names; and that the power of Attraction is implanted in the parts of attracting bodies, in the ſame manner as that quality or property is implanted, which diſpoſeth a moved body to perſiſt in its ſtate of uniform motion, and to proceed in a right line.

In this reaſoning to the cauſe of attraction, I have kept in my view every known part of matter, and every known variety of attraction

tion; that the concluſions might appear with their full force to thoſe who are converſant in Natural Philoſophy, and who know that ſuch concluſions are the more admiſſible by how much they are more general; and although other arguments affording the ſame concluſions might be introduced; the arguments, for inſtance, ariſing from the obſervations already made of compounds, which invariably exhibit properties different from thoſe of the homogeneal component parts; and from the obſervation made of maſſes, which being formed of homogeneal parts united by attractive powers, do exhibit no properties notably different from thoſe of their parts; by which obſervations we learn that the attractive and repulſive powers are inherent in the parts of bodies, and are ſimplified as the bodies are reſolved, and are compounded as the bodies are compounded; I content myſelf with the arguments already ſtated, becauſe my chief deſign at preſent is, by a few comprehenſive and conciſe remarks to lead the reader into a train of reflection on particulars, whereby he may be eaſily convinced that neither chemical, electrical, magnetic, nor capillary attraction, nor the attraction of cohesion, nor that of gravitation, nor any other attraction is the effect of any material agent exterior to the attracted bodies; and alſo convinced that repulſion is not cauſed by any material agent exterior to the repelled bodies; but that attraction and repulſion are effects of innate powers or virtues of the parts of all known matter.

Although Chemiſts have ever laboured much in the examination of bodies, it is not a long time ſince philoſophers began to enquire diligently, and to reaſon from their own experience, concerning the minute parts of bodies and their properties. Our knowledge of the relations of the parts of groſs bodies is yet in its infancy; and it is therefore perfectly excuſable in the ableſt writers on the ſubject of Light, that they appear ignorant of its relations, and cannot explain the phenomena of the reflection and refraction of Light, without aſſuming an ethereal fluid.

As Ether is not the cauſe of the relations of groſs bodies towards each other, and is not neceſſary towards their mutual action on each other, whether they be in contact or diſtant, ſo an Ether is not neceſſary towards the mutual relations and actions of the matter of Light and of groſs bodies ; and as the exiſtence of an Ether is not proved, it ought for theſe reaſons only to be rejected in optical reaſoning. But there are other reaſons for our rejecting it ; and theſe will occur as we proceed to ſhew that Light itſelf is a fluid diffuſed in all known ſpaces, like the imagined Ether ; and as we attempt to explain the optical phenomena conſiſtently with the inherent powers or the properties of matter, whoſe exiſtence is incontrovertible.

SECT. IX.

Notions concerning the ſimple Powers of Attraction and Repulſion, preparatory to the Conſideration of compounded Powers.

OUR knowledge of the attractive and repulſive powers already noticed in a ſummary manner, commences with obſervations on particular homogeneal ſubject which attract or repel, and advances with the number of theſe, untill an enlarged view of all affords general inductions. When theſe inductions are ſubmitted to the teſt of new experiments, and are confirmed by them; and when they are found to aſſiſt us in developing the operations which before appeared inexplicable; they are then to be aſſumed as phyſical axioms. Such is the order in which I have inveſtigated theſe ſubjects, altho', for the ſake of brevity, I have in the foregoing Sections treated of them in another method; and ſuch is the evidence which I intend, on a future occaſion, to offer in ſupport of the notions which I am now about to propoſe, with a view towards recommending thoſe already expreſſed, and towards facilitating our intended enquiries concerning Light. And I wiſh it to be noticed, that I mean here only to propoſe them, ſo as to ſhew their conſiſtency with each other and with nature; and that when I ſubjoin illuſtrative inſtances to prove them, theſe are to be conſidered, as the moſt familar or conciſe, not as the only proofs that we can offer.

NOTION I.

Earthy Atoms attract each other.

Illuſtration.

THE reciprocal attraction of earthy atoms appears in the ſolid earthy aggregates whoſe parts cohere with great force; as in jewels and hard ſtones, ſtalactites, petrefactions, porcelain, pottery, bricks, flags, glaſſes, cements, artificial ſtone: it alſo appears in veſſels of plaſtic earthy compoſition, which preſerve their figure in drying; for if the parts of ſuch veſſels were not drawn towards each other by an attractive power, they would collapſe during the exſiccation. The ſame attraction appears in all compounds conſiſting chiefly of earth; and is moſt remarkable in tenacious metals; in allays, in ſoldering, gilding and other metallic adheſions, in metallic ſublimates and glaſſes. And altho' in many of theſe earthy bodies, other matter may aſſiſt in cauſing the forcible coheſion of their parts, it is nevertheleſs evident that the earthy parts themſelves attract each other with conſiderable force; for no matter beſides earth appears in all or is common to all the ſolid maſſes enumerated.

NOTION II.

Atoms of Water attract each other.

Illuſtration.

THE reciprocal attraction of watry atoms, appears in bubbles, drops, and ſtreams of water; in rain, dew, and condenſations of aqueous vapour; in the riſing of water in ſnow by capillary attraction; by the ſuſpenſion or ſlow ſubſidence of fine powders in water, as in the proceſſes for aurum fulminans, caſſius precipitate, uncombined magneſia, precipitated earth of alum, and of quartz, and in many other proceſſes; but eſpecially in water diveſted of Fire and frozen.

NOTION III.

Atoms of Earth and of Water, attract reciprocally.

Illuſtration.

THE reciprocal attraction of earth and water appears in wetting, in drops of water ſuſpended by earthy bodies; in the coheſion of plates of ſtone, glaſs, metal or any homogeneal or compound earthy matter, by means of interpoſed water; in the riſing of water between ſuch plates, its accelerated motion towards the concurrence of them, when they form an angle ; and the riſing of water to great heights in capillary tubes and ſpongy maſſes of earthy matter, or in ſands and powders, contrary to the gravitation of water ; in overfilling veſſels with water ; in the ſuſpenſion of iſickles from ſtones or any maſſes of earth however ſmooth ; in obſerving the intenſe heat neceſſary to vaporize or expel water from the compoſition or pores of earthy bodies ; and in many other inſtances.

NOTION IV.

Atoms of Water and of Air, attract each other.

Illuſtration.

THE grounds of this Notion appear in the great quantities of water ſpeedily attracted from atmoſpheric air, by concentrated acids, by fixed vegetable alkali, various neutral, metallic and earthy ſalts, and other compounds ; in the drying of wet cloths in the air ; in all drying houſes, and graduating houſes ;

houſes; in the quick diſſipation of moiſture breathed on glaſs, and other ſmooth bodies, particularly metals; in the loſs of weight and water of cryſtallization, from Glauber's ſalt, mineral alkali, and other ſaline compounds, when they are expoſed to dry air; in the effects of ſuch air on hygrometers and other inſtruments; in depoſitions of water from cooled atmoſpheric air; in our late experiment, wherein air heated and otherwiſe affected by paſſing through a red hot iron body, and then cooled in proper veſſels, depoſites therein much water; in various pneumatic experiments well known; in the air obtained from water which has been expoſed to air; and in the water obtainable from every portion of air which has been expoſed to water.

NOTION V.

Earthy and Acid Matter attract each other.

Illuſtration.

THIS attraction appears in the adheſion of the pureſt acid matter to ſtones and all earthy maſſes whoſe aggregation is ſo powerful as to prevent them from being diſſolved: It further appears in the native compounds conſiſting chiefly of earth and acid; as in fluors, ſelenites, gypſum, alum, and native metallic ſalts; but moſt conſpicuouſly in the ſolutions of earthy bodies in acids, and the compounds conſequently formed, ſuch as the earthy and metallic ſalts; and in the concentration and abſorption of acid elaſtic fluid, by ſeveral earthy bodies ſuſpended therein; and in the volatility of many of the moſt fixed earthy bodies when combined with acid.

NOTION VI.

Water attracts Acid.

Illuſtration.

THIS attraction is evident in the ſeveral acid bodies which attract water from the air; and in the ſeveral acids of the chemiſts; and in the ſudden melting of ice by acid; but eſpecially in the condenſation and abſorption of any acid elaſtic fluid by water. For when a veſſel is filled with ſuch elaſtic inviſible fluid counterpoiſing the preſſure of the atmoſphere, and when a little water is introduced into the veſſel, the whole of the acid elaſtic fluid is imbibed by the water; its elaſticity ceaſes; and the water ſo impregnated is ſimilar to one or other of the acids diſtinguiſhed in chemiſtry.

NOTION VII.

Water attracts Alkali.

Illuſtration.

THE fixed alkaline bodies called vegetable fixed alkalies, greedily imbibe moiſture from the air ; diſſolve in a ſmall quantity of water, and retain water for a long time in ſuch degrees of heat as water alone cannot abide a moment without being vaporated. Theſe denote the attraction ; but it appears more evidently in the following inſtances. Ice diſſolves quicker in the alkaline elaſtic fluid, in the coldeſt weather, than in a heat equal to 150 of Ferenheit : and if ſal ammoniac or any body containing volatile alkali, be decompoſed by metallic calces or lime, without the addition of water, the alkaline matter paſſes off in form of an elaſtic incoercible fluid : but if water is uſed in the proceſs, or if the elaſtic fluid is paſſed into water, we obtain the watery alkaline fluid called cauſtic volatile alkali : and when a veſſel is filled with the elaſtic alkaline fluid, and a little water is introduced to this fluid; the alkali is imbibed by the water; its elaſticity ceaſes; and the united water and alkali form the cauſtic volatile alkali of the chemiſts.

NOTION. VIII.

Acid and Alkali attract each other.

Illuſtration.

ALL known acid and alkaline bodies are known to attract, and combine with each other; but the mutual attraction of homogeneal acid and alkaline matter is moſt apparent when we mix the elaſtic alkaline and acid fluids; for thoſe which ſeverally are permanently elaſtic and inviſible, do, when mixed condenſe each other, and form a viſible palpable ſalt, occupying not a thouſandth part of the ſpace wherein either of the elaſtic fluids were previouſly contained.

NOTION IX.

Acid and Phlogiſton attract each other.

Illuſtration.

THIS attraction is known to all chemiſts and is eaſily perceived in the formation and decompoſition of ſulphur, *gas ſulphuris*, phoſphorus of *Kunkel*, ardent ſpirits, ethers and many other compounds conſiſting chiefly of acid and phlogiſton; and it is moſt unexceptionably inſtanced in the compound fluid called inflammable air: For this elaſtic inflammable fluid is formed in divers ſolutions, in the action of acids on inflammable bodies, in putrefactions and pyritous decompoſitions, and whenever acid and phlogiſton are ſet at liberty to unite; and this fluid is obtainable, by ignition, from charcoal, oils, mineral fuel, and almoſt every animal, mineral or vegetable ſubſtance which contains acid and phologiſton combined with any matter that is more fixed than theſe are;

and no matter eſſentially neceſſary to the compoſition of inflammable air, except acid and and phlogiſton, is common to all theſe bodies and in all theſe proceſſes; and no other matter, beſides acid and phlogiſton, is diſcoverable in the analyſis of inflamable air; and divers experiments ſhew that the acid of inflammable air is combined and ſaturated with phlogiſton and conſequently adherent thereto, by a power of attraction.

NOTION X.

Phlogiſton and Earth attract each other.

Illuſtration.

THE ſeveral ſemi-metals which are combuſtible, and whoſe calces or earths draw phlogiſton from ſeveral thouſands of phlogiſtic compounds; and the metals, which are not commonly accounted combuſtible bodies, but which nevertheleſs are found, in calcinations, ſolutions, vitrifications, ſcorifications with nitre, and many other operations, to contain phlogiſton as a conſtituent part of their ſubſtance; are all inſtances of the attraction of phlogiſton to earth; inaſmuch as phlogiſton and earth contribute chiefly to the maſs of theſe bodies, and nothing but phlogiſton and earth is found in the compoſition of every one of them; and becauſe the phlogiſton and earthy matter could not cohere to form denſe ſolid bodies, unleſs by means of an attractive virtue.

Culm, mineral coal, jet, bitumens, and a great number of mineral ſubſtances, which burn freely, or are uſed as fuel, are by diſtillation and other operations, ſuch as that called *coaking*, found to conſiſt of ſeveral ingredients which are ſeparable from any one of theſe bodies, whilſt nearly the whole of the earthy matter remains fixed and aſſociated with phlogiſton. This forcible adheſion of the phlogiſton to the earthy matter of ſuch maſſes, muſt be conſidered as a ſtrong indication of the attraction of phlogiſton to earth; until it appears, by ſome new experiments, that in all coaks and reſiduary portions of ſuch diſtilled bodies, the phlogiſton is held united with the earthy parts, by the mediation of ſome other matter, common to all theſe charred reſiduary portions.

Chalks, marbles, and all native calcarious concretes which become duſky or blackiſh in colour, when heated in cloſe veſſels, and which in ſolution, and in the decompoſition of ſal ammoniac, and in many other operations, yield the phlogiſtic compound elaſtic fluid commonly called fixable air, or which may be calcined to lime which cauſes heat when ſlacked with water: liverſtones and odorous ſwineſtones, ſeveral marles, all grey and blackiſh clays which may be calcined to whiteneſs; many coloured gems and quartoſe ſtones, brown or dark coloured flints which in calcination become white; the mineral ſubſtances called black leads and magneſe; and ivory black, and diſtilled bones; are inſtances of earthy matter aſſociated with a ſmall quantity of phlogiſton, which is diſcoverable in them by the means of nitre, or in ſolutions, or in vitrifications, or other operations, whereby we detect ſmall portions of phlogiſton in bodies which are not apparently combuſtible, like ſea coal, zinc, tin and other ſubſtances: For no compound phlogiſtic body is freely combuſtible, when its phlogiſton, deficient in quantity, is covered and defended from the action of air; which either combined, as in nitrous acid or nitrous ſalts, or uncombined, as the greater part of atmoſpheric air is, muſt be cloſely applied to the phlogiſton of plogiſtic compounds, before they can enter into combuſtion; that is to ſay, before the phlogiſton can be withdrawn from them, ſo as to appear in the character of Fire. The phlogiſton, therefore, of the ſeveral bodies laſt enumerated, is certainly held in them by a power of attraction; and there is no reaſon to preſume that, in all theſe inſtances, the phlogiſton is held united to the earth, by any other cauſe beſides that of the attraction of earth and phlogiſton to each other.

We might proceed to other inſtances of the attraction now under conſideration; and particularly to thoſe which may be derived from the operations wherein double elective attractions are noticed by the Chemiſts; or to thoſe which may be borrowed from the arts which exhibit the diſpoſition of white earthy bodies to attract Phlogiſtic matter from the open Air, and to be coloured thereby: and the phenomena which occur in the preparation of Solar Phoſphori, which exhibit various colours whilſt they illuminate, might alſo be recounted as illuſtrating the attraction of Phlogiſton to Earth. But all theſe are omitted; becauſe the Phlogiſtic compound bodies, before mentioned, indicate the attraction of Phlogiſton to Earth, as much as is neceſſary towards our future inveſtigations, in which no great ſtreſs will be laid on the notion that pure earthy matter attracts pure Phlogiſtic matter; and no more will be peremptorily aſſumed than the well known attraction of divers earthy maſſes to the Phlogiſtic element.

NOTION XI.

Phlogiſton and Air attract each other.

Illuſtration.

EVERY metallic Earth which is combined with Phlogiſton, ſo as to form a metal or ſemimetal, retains this Phlogiſton, however it be expoſed to the action of Fire only; as when metals are ſtrongly ignited and defended from the action of air, either by fluxes or by veſſels impervious to Air. But the ſame metallic bodies, which ſuffer no alteration by long continued ignition, fuſion, or ſublimation, in cloſe veſſels, are quickly decompoſed when they are in any of theſe operations expoſed to air; and the Phlogiſton is in all operations of this kind drawn from the metallic earths ſo much the ſooner, as they are more fully expoſed to the action of Air. This is apparent in all calcinations, in the art of aſſaying, in ſcorifications, in teſting, and in the uſe of ſoldering fluxes; and it may be beſt exemplified to thoſe who are not well acquainted with metallurgy, in the metallic ſubſtance called zinc; which may be ſublimed or diſtilled from one veſſel into another without any alteration, if air be excluded; but ſuddenly blazes and burns vehemently when air is admitted during the ſublimation; the white earthy matter only of the Zinc remaining after the combuſtion.

All Phlogiſtic compounds which may be heated to redneſs without being vaporated, abide ignition long continued, in cloſe veſſels, without looſing any notable part of the Phlogiſton. But the ſame bodies, of which many thouſands might be enumerated, under the following heads, pyritous bodies, coaks, culm, the black earths, the chared reſidues of all mineral inflammable bodies, chared bones, horns, and other chared reſidues of ſolid and fluid animal parts, the chared coals and phlogiſtic fixed alkaline ſalts of all vegetable ſubſtances; are all calcined or deprived of Phlogiſton, quickly or ſlowly, as air is admitted to them whilſt they are heated, and as they are, by comminution, expoſed with a greater or ſmaller extent of ſurface, to the admitted air.

All mineral, vegetable and animal ſubſtances, which are or may be uſed as fuel, however ignited in veſſels which exclude air, and however analyſed into different compounds, do retain, partly in the diſtilled or ſublimed portions, and partly in the reſidues, the Phlogiſton which was combined in theſe ſubſtances: but all theſe burn, conſume, and are deprived of Phlogiſton ſooner or later, in proportion to the quantities of air ſucceſſively admitted to them whilſt they are heated.

Subſtances in which a conſiderable quantity of Phlogiſton is united with acid or alkaline matter, and which containing very little earth, are volatile and freely inflammable; ſuch as fats, oils, reſin, balſams, bitumens, eſſences, camphors, benzoin-flowers, ardent ſpirits, Ethers, ſulphur, and the Phoſphorus of *Kunkel*; all retain their Phlogiſton, however they be heated, vaporated or diſtilled, ſo long as air is prevented from coming into contact with them: but every one of theſe burns and is deprived of Phlogiſton, ſlowly or rapidly in direct proportion to the ſlow or rapid admiſſion of air, and the extent of ſurface which theſe bodies when heated preſent to the air. Even the elaſtic inflammable fluids retain their Phlogiſton however they be heated in cloſe veſſels, and their decompoſition or combuſtion is ſlow or rapid, as the quantity of air admitted to them is ſmall or great.

The moſt fixed phlogiſtic bodies, ſuch as metals, ivory black, coak, charcoal, may be heated to the moſt intenſe degree in the *Torricellian* void, by the collected ſun-beams, and may be fuſed and vaporated thereby, without burning or loſing their Phlogiſton; but the ſame bodies, leſs heated in the ſame manner, are calcined or burned and deprived of Phlogiſton, in direct proportion to the quantity of air admitted. Sulpur, oils, ether, inflammable air, and all volatile inflammable bodies, treated in the like manner, are alſo found to burn only in direct proportion to the quantity of air introduced to them; and Phoſphorus of *Kunkel*, which is lucid and looſes its Phlogiſton in temperate air, may be heated by ſun light to boil in the *Torricellian* void, without burning, illuminating, or being deprived of its Phlogiſton; but on the admiſſion of air, the heated Phoſphorus burns vehemently; and when the acceſs of freſh air is prevented, the combuſtion languiſhes and ceaſes. The Pyrophori, moreover, may be heated to redneſs in veſſels void of air, without being deprived of their Phlogiſton; but the very ſame compounds, whether they be expoſed to fire or not, burn and looſe their Phlogiſton quickly or ſlowly, in the direct proportion of the quantity of ſurface which they expoſe to air, and of the quantity of air admitted to them in a given time.

Now ſince the quantity of fire produced from combuſtible bodies, is ever directly proportionate to the quantity of phlogiſton which is detatched from the other matter of them; and ſince the quantity of fire ſo produced and of phlogiſton ſo detatched, is, without notable error, directly proportionate to the quantity of air applied to heated or burning bodies; provided we exceed not the neceſſary quantity of air, and provided the portions of air employed be equally pure or equally impure: and ſince no combined matter, beſides phlogiſton, appears to be common to ſo many thouſands of bodies, which differ in their compoſition and properties, as iron differs from phoſphorus of urine, or as ivory black differs from the inviſible elaſtic inflammable fluids; the efficacy of air, towards drawing phlogiſton away from every kind of matter with which it is combined in all theſe compounds; That is to ſay, *the attraction of phlogiſton to air*, is ſufficiently apparent.

In the modern proceſs for making oil of vitriol; in the ſlow ſolution of tin and other metals, in the nitrous acid; in the diſtillation of nitre of lead and of ſundry earthy ſubſtances impregnated with the nitrous acid; and in the curious decompoſition of nitrous ammoniac, diſcovered during the late meetings above mentioned, and effected by diſtilling nitrous ammoniac, and paſſing the vapour thereof thro' water into an inverted veſſel void of air; and by divers other experiments; we learn that air is indiſputably a component part of the nitrous acid, and is ſeparable from the other ingredients of this acid; and of this knowledge the artiſts ought to avail themſelves, in the management of ſalt-petre-beds, and in the cryſtallization of nitre for exploſive mixtures: We moreover find that this air, whether detached from the other ingredients of the nitrous acid, or combined with them, ſo that water ſhall not be predominant in the compound, acts like atmoſpheric air, on heated phlogiſtic bodies. For metallic ſubſtances, fuel, ſulphur, phoſphorus of *Kunkel*, alkohol, ether, inflammable air and all the tried combuſtible bodies, are experimentally proved to enter into combuſtion, and to perſiſt in the act of burning; as well, when the vapour of dephlegmated nitrous acid acts on them, in conjunction with fire; as when common air acts on them, in the like circumſtances: and the nitrous acid combined with alkaline ſalt, and thus enabled to ſuſtain a great charge of fire without being vaporated, when mixed with phlogiſtic bodies, does contribute to their combuſtion,

buſtion, and does deprive them of phlogiſton, as effectually as uncombined air can do.

The nitrous compounds; in which the nitrous acid, held combined with fixed vegetable or mineral or volatile alkali, or with certain metallic and unmetallic earths, is not at liberty to act by its acid part on compound phlogiſtic bodies, ſo as to decompoſe them without the aſſiſtance of fire; are all found to act like air on heated combuſtible bodies. For each phlogiſtic compound requires as great a degree of ignition, for its combuſtion, when nitre acts on it, as when air acts on it: charcoal, for inſtance, will not burn with nitre in cloſe veſſels until the nitre or the charcoal be heated to redneſs: Sulphur will not burn, in cloſe veſſels, with nitre, until the ſulphur and nitre be heated as much as is neceſſary for the free combuſtion of ſulphur in open air; or rather more. Mixtures of nitre, ſulphur and charcoal, ſuch as gunpowder is; and divers other mixtures of phlogiſtic bodies with nitrous compounds, require to be ignited, in ſome part of them, before they can enter into combuſtion, in cloſe or open veſſels. The vapour of dephlegmated nitrous acid which exhales a thick white fume when duly prepared, aſſiſts in the combuſtion of bodies, in the ſame manner as air doth; and when this vapour is applied to phlogiſtic compounds which it cannot decompoſe; as when it is mixed with inflammable air; the mixed fluid will not burn, until ſome part of it be ignited, as it happens when we apply to it the blaze of a taper. All combuſtions, ſcorifications, and detonations, are more or leſs rapid, as the nitrous compounds are more or leſs intimately blended with the phlogiſtic bodies to be ſcorified, inflamed, or exploded by the joint action of fire and nitrous compounds. Nitre, for inſtance, in the quantity of three drams, ſulphur weighing two drams, and ſalt of tartar one dram, Troy-weight, being intimately blended with each other by fuſion *(which is a dangerous operation)* form a pale yellow pulverable maſs, which on its contact with a flint-ſpark, burns more inſtantaneouſly than gunpowder, and with a more dreadful exploſion, eſpecially when the maſs is heated before the flint ſpark is applied; as I have often experienced: But the ſame materials only ground together in theſe proportions, or in the proportions uſually preſcribed for fulminating powder, burn ſo ſlowly, that we may ſtand cloſe to the open culinary fire into which we throw a pound of the mixture at once. In the like manner, the materials of gunpowder, when they are imperfectly mixed, burn ſlowly : but when they are well ground together, as is done in making gunpowder, they catch fire eaſily and burn rapidly. So likewiſe the powder of charcoal well mixed with that of nitre, burns vehemently and with dangerous exploſion, when the mixture is heated to redneſs in a cloſe veſſel : but the ſame quantity of charcoal in one round ſolid lump, heated to redneſs with the ſame quantity of nitre, burns ſo ſlowly, that we attend the operation with ſafety, whilſt it is performed in glaſs veſſels ; and we ſave and examine the elaſtic fluids detatched during the combuſtion.

In theſe and divers other inſtances we perceive the cloſeſt analogy between the effects of nitrous compounds, and thoſe of air, on heated phlogiſtic bodies ; and the analogy is the more ſtriking, by how much we try it more ſcrupulouſly. A lump of copal or of amber, or a dram of lycoperdon powder compacted, expoſed to the blaze of a candle, burns ſlowly; as a lump of charcoal burns ſlowly in contact with heated nitre: but the levigated powder of copal or of amber, equal in quantity to the lump of either of theſe, or the dram of lycoperdon powder, blown forth, and diffuſed in air, and then meeting the blaze of a candle, burns as much more rapidly than it did in the former circumſtance, as the combuſtion of gunpowder is more rapid than that of an equal quantity of charcoal, in the ſolid lump, floating on red hot nitre. In the like manner, volatile oils, ſpirits and ethers, which, being inflamed by the blaze of a taper, burn ſlowly on the ſurfaces of them expoſed to air; do all burn rapidly with one exploſive momentary flaſh, when in the form of vapour they are blended with air, and then meet the taper-blaze.

As phlogiſton is detached from metals and moſt other phlogiſtic compounds, when concentrated acids act on them and combine with the matter which held the phlogiſton of ſuch compounds in a ſtate of combination ; as heat is produced whenever the phlogiſton is thus detatched ; as the acid matter of nitrous acid acts to this effect ; and as the nitrous acid, at the ſame time that it heats phlogiſtic bodies, ſupplies the air which is neceſſary for the rapid combuſtion of them ; the foregoing analogy is not more perfect in the inſtances recited, than it is in the combuſtion of oils, phoſphorus of *Kunkel*, and of other bodies, by the ſole action of the concentrated nitrous acid ; or than it is in thoſe combuſtions which we lately diſcovered : as in the ſparkling combuſtion of the powder of regulus of antimony dropt into a narrow mouthed veſſel filled with the acid vapour ariſing from four parts of dephlegmated nitrous acid with one part of ſtrong marine acid ; or in the ſparkling and exploſive combuſtion of tinfoil ſtratified briſkly with moiſt nitrous ſalt of copper, and coiled up cloſely.

It is moreover obſervable that the quantity of phlogiſton, extricated from any body, during the calcination ſcorification or combuſtion

tion, in which a nitrous compound acts as a ſubſtitute for air; is as the quantity of the nitrous compound employed, until the quantity neceſſary to the total dephlogiſtication is applied: and this obſervation relates to ſo many obvious inſtances, and is ſo free from experimental exception, that it needs no illuſtration.

Since atmoſpheric air acts in combuſtions by virtue of its attraction to phlogiſton; and ſince nitrous compounds contain a conſiderable quantity of true air; and ſince theſe compounds aſſiſt in the combuſtion of bodies, as air doth; all ſcorifications, calcinations, flaming combuſtions, and fiery exploſions, which are effected, in cloſe veſſels, by the aſſiſtance of nitrous compounds; denote the attraction of air to phlogiſton.

When ſulphur and iron-filings are mixed in equal parts and moiſtened briſkly with water, in a veſſel which perfectly excludes air from the mixture ſo ſoon as it is made; very little, or none of the phlogiſton of the ſulphur or of the iron, is found to depart in the courſe of ſeveral weeks; although the colour of the mixture may be changed to blackneſs of the ſuperficial parts. But if ſix or ſeven pounds of the like mixture be expoſed in an open veſſel, for a few hours, it grows hot and and burns languidly, until there remains only an incombuſtible compound, conſiſting of martial earth and vitriolic acid united. If ſulphur be combined with fixed alkali, either by ſolution or fuſion; and if the compound, called hepar ſulphuris, thus formed, be kept in well-ſtopped veſſels, it undergoes no change for a number of years: but if the ſame hepar ſulphuris be finely powdered, or diſſolved in water, and expoſed to air, the phlogiſton is ſoon drawn away, and the reſiduary matter is found to be an incombuſtible ſalt. Theſe are only a few of the many phlogiſtic compounds which undergo no ſenſible alteration in cloſe veſſels, or in the *Torricellian* void; but which are gradually deprived of their phlogiſton by the agency of air, unaſſiſted by any extraneous fire. In all theſe inſtances, it appears that air attracts phlogiſton.

Glaſs-makers, aſſayers, and divers artiſts, as well as the chemiſts, have obſerved that ſolid earthy bodies, which are accounted fixed bodies, when reduced to powder, and ſuddenly heated, do diſcharge a conſiderable quantity of elaſtic fluids, which blow the powders forth, and cauſe great intumeſcence of the maſſes at the time of their fuſion. Monſieur *Lavoiſier*, in the year 1773, diſcovered, and in the year 1774 publicly ſhewed, that during the calcination of certain metals, a conſiderable quantity of atmoſpheric air combines with the calces, and may be expelled from them in a ſtate of uncommon purity, by the action of fire: and in the latter part of the ſucceeding year, experiments ſimilar to thoſe of the *French* academician, were exhibited and publiſhed in *London*.

Theſe publications may incline philoſophers to object to theſe inſtances of the attraction of air to phlogiſton, for this reaſon; that as an acid expels the phlogiſton from a metal which it diſſolves; or as vitriolic acid expels the the marine from ſea-ſalt or *ſal ammoniac*; ſo air may be inſtrumental in the detachment of phlogiſton from phlogiſtic bodies, by reaſon of its affinity to the matter which holds phlogiſton

giſton in theſe bodies, rather than by mea of any attraction of air to phlogiſton. But o the following conſiderations, this objectio appears groundleſs.

Firſt, Of the many ſubſtances which ar dephlogiſticated by the action of air, only a few yield air when ignited; and it is not to be preſumed that air takes the place of phlogiſton, in all bodies that are deprived of phlogiſton, until this is proved by experiments.

Secondly, Air which has aſſiſted in the dephlogiſtication of any phlogiſtic compound; ſuch as the air is, which has paſſed through burning fuel, or in which any phlogiſtic body has been calcined, or inflamed, or burnt; or the air which has once acted on Pyrophori, Phoſphorus, Hepar Sulphuris, the mixture of Iron filing and Sulphur; or the air which by any known means is impregnated with Phlogiſton; is found incapable of acting like pure air on phlogiſtic bodies, the Phoſphorus of *Kunkel* not excepted; and ſuch air as effectually extinguiſhes flaming bodies, as if they were immerſed in water. As the phlogiſton of any known body has this effect on air; and nothing but Phlogiſton can reaſonably be preſumed to proceed from every one of the phlogiſtic compounds, to unite with air; and as Phlogiſton certainly does eſcape from them all, during the operations wherein air acts the part already expreſſed; and as the air appears to be altered in its properties, in conſequence of its union with Phlogiſton, as all homogeneal bodies are by combination; and as air is contracted in its dimenſions, by this acceſs of Phlogiſton, as every elaſtic fluid is reduced in volume by the admixture of another fluid, when the parts of ſuch fluids attract each other; we rather conclude that air attracts Phlogiſton, and being ſaturated thereby, is incapable of drawing more; than that air is capable of expelling Phlogiſton from the bodies, by reaſon of its ſuperior attraction to the matter which holds Phlogiſton in them.

Thirdly, If the attraction of air to Phlogiſton be denied, whilſt it is aſſerted that air attracts every other kind of matter which enters the compoſition of phlogiſtic bodies; no reaſon can be aſſigned to explain, why the air, which has been inſtrumental in detaching a ſmall portion of Phlogiſton from a phlogiſtic compound, does not continue to expel Phlogiſton, until the whole quantity of air employed, is combined in the place of the extricated Phlogiſton.

Finally, it is repugnant to the beſt eſtabliſhed maxims of experienced Chemiſts, to ſuppoſe that earthy, acid, alkaline bodies, and compounds of theſe, attract air more forcibly than they attract Phlogiſton; and it is raſhly preſumed that air expels Phlogiſton from phlogiſtic compounds, by reaſon of its more forcible attraction to the reſiduary matter of ſuch compounds; ſince it doth not appear that air attracts every kind of matter with which we ſind Phlogiſton combined or combinable.

But if it ſhould hereafter appear, that air takes the place of Phlogiſton, during the combuſtion of all bodies; the attraction of Phlogiſton to air, will ſtill appear, in experiments which I have not yet inſiſted on.

I ſhall not proceed to conſider the other ſimple attractions of homogeneal bodies; becauſe they are numerous, and require much illuſtration; and becauſe thoſe that I have mentioned may ſuffice, until we treat of the attraction of Light to other matter.

Notion XII.

Each natural Part of Matter doth not attract every other Part: For the ſimilar Atoms of divers Elements repel each other.

Illuſtration.

THE experiments, by which we learn that the parts of air repel each other, are well known, and this repulſion is univerſally admitted.

When homogeneal alkaline matter is detached fram ſal ammoniac by the means of metallic calces, or lime, or cauſtic fixed alkali; and when the alkaline matter of volatile ſalt of ſal ammoniac, or of hartſhorn, is diſengaged by lime, or cauſtic fixed alkali, or otherwiſe; and when we receive the alkali thus detatched from compound bodies into the *Torricellian* void; we find it in the form of an inviſible fluid ſtrongly and permanently elaſtic like air, and equally manifeſting the repulſion of its parts to each other, in every experiment made on it.

Acid matter likewiſe, when diſengaged in various operations, and confined untill it burſts the containing veſſels; or when received tolerably pure, into the *Torricellian* void, and examined in the foregoing manner; is found to conſiſt of parts which repel each other, as evidently and almoſt as forcibly as the parts of air repel each other.

Although phlogiſton, when diſengaged from the other matter of phlogiſtic compounds, eſcapes through the veſſels and eludes the examinations to which other inviſible fluids have been ſubjected; we are, nevertheleſs certain that atoms of phlogiſton repel each other. For this repulſion is denoted by the rapid expanſions and eſcape of this matter when it is de-

detached, in combuſtions, fulminations, ſolutions, vitriolizations, fermentations, putrefactions, and in the decompoſitions of pyrophori and phoſphoreſcent bodies: It is alſo denoted in the forcible expanſions of fire, when phlogiſton appears in that character, or compoſition; likewiſe in phlogiſtic air which is an elaſtic fluid; and moſt clearly in the elaſtic fluids, in which this repulſion aſſiſts in counteracting the attraction of phlogiſton to acid, ſo far as to admit only an approximation of parts, and to prevent the formation of a ſolid body; as will better appear in the ſection concerning ſaturation.

We muſt hereafter take notice of other repulſions: and thoſe who conſider the electric fluid as an element, may rank the repulſion of its parts with the foregoing repulſions of homogeneal parts.

NOTION XIII.

The Power of Repulſion is not exerted between all the Atoms of Matter indifferently.

THIS appears from the inſtances of attractions.

NOTION XIV.

The ſimple Attractive Powers are not all equally forcible; one of them having greater efficacy than another, and this greater than a third, and ſo on, by ſeveral gradations.

Illuſtration.

THE evidences of the truth of this notion, are as numerous as the combinations and decompoſitions which are effected without the aid of Fire; and they appear in the tables of elective attractions, and ſtill better in the experiments made on the more homogeneal bodies, The pureſt acid matter which we can procure, attracts water, and earth more forcibly than water, and alkali more forcibly than earth ; for it will quit water to unite with earth, and earth to unite with alkali. There are other forces intermediate between theſe ; and the like gradations of attractive forces are obſervable in the other elements, and are generally admitted.

Enquiry ought to be made concerning the gradations of repulſive powers, which powers do not ſeem to be equally forcible in all kinds of matter.

NOTION XV.

The Atoms or Bodies which cohere or mutually attract, when in Contact, do exert a Power of Attraction relatively to each other, at all Diſtances of them.

Illuſtration.

WHEN earth is diſſolved in any menſtruum, and the menſtruum is quickly ſaturated with any other matter, the earth, no longer held by a forcible attraction, yields to the force of gravitation, and is precipitated. But if the earth be ſlowly detached from ſuch menſtrua ; if, for inſtance, liquor ſilicium be expoſed to the vapour of marine acid, and the liquor be held in a quieſcent ſtate ; the earth ſo detached from the alkaline menſtruum cannot quickly ſubſide, by reaſon of its fineneſs and the tenacity of the menſtruum ; and as its gravity dees not in this circumſtance counteract the force of attraction of the parts, this force produces manifeſt effects ;

for a ſolid aggregate is formed, adhering to the veſſel, and contiguous to the ſurface of the liquor. As the earth is not, in this inſtance, an hundreth part of the liquor ſilicum, and as it is equably diffuſed therein, its parts muſt be conſiderably diſtant; and when we ſee theſe diſtant parts drawn into contact with each other and with the glaſs veſſel, and forming an aggregate, which becomes ſolid in proportion as it dries; It is plain that particles of earth attract each other at a diſtance, though not ſo forcibly as in contact of them.

The like experiments made on a variety of earthy ſolutions in acids and alkalies, furniſh the ſame concluſion.

When we conſider the diſtance to which the parts of earthy bodies muſt be removed from each other in all ſolutions, and that an aggregate cannot be formed from ſuch ſolutions, in any place different from that to which gravity would incline theſe parts, unleſs there were a power of attraction operating on them; every inſtance in which an aggregate is formed in ſuch circumſtances, is an evidence proving that earthy particles attract each other at a diſtance.

Such inſtances we have, in the cruſt adhering to glaſſes and pottery in which lime water is kept; in the cruſt which forms on the ſurface of lime water, unleſs exceptions ariſe from the addition of fixable air; in the gold depoſited in a coherent ſplendid metallic condition from ethereal ſolutions; in the formation of ſpars and ſtalectites, whoſe parts gradually gathered from waters in which they were widely diffuſed, coaleſce in all directions, as well as in that of their gravitation; and in petrefactions of vegetable and other ſubſtances, to which earthy matter concretes, as faſt as the vegetable matter is waſhed away, in certain Lakes and waters impregnated with earthy matter.

All ſolid earthy bodies are in ſome degree flexible; ſome metals in the higheſt degree; talc, aſbeſtus, and other ſtoney bodies, and glaſs, in a lower degree; for unleſs they are thin they cannot be much bent without breaking. All other bodies that are leſs flexible than theſe, may nevertheleſs be bent a little. Columns of marble or porphyry are tremulous to thunder, exploſions and certain tones of organs; and ſteeples rock conſiderably in high winds, or ringing heavy bells: And bells made of the moſt brittle allays, and porcelain and pottery duly faſhioned, are capable of ringing loudly. Theſe happen without ſolution of continuity in glaſs, pottery, ſtones, cements; and therefore denote flexion in all theſe bodies. But in all flexures of bodies which can recover their former poſition, there muſt be an elongation on the convex ſide; and this denotes a ſeparation of the parts; and the recovery from flexure denotes a power of attraction exerted to a diſtance, and effecting the union of the ſeparated particles.

When metals are ſwelled by fire and fuſed, and when glaſs is fuſed, the parts of theſe muſt be diſtant, ſince the volume is greater. Yet in this condition the attraction is manifeſt, in the round drops which they form; in their tenacity, in their ſhrinking and forming ſolid bodies, in proportion as the

Fire is removed, without the aſſiſtance of gravity. For a drop of metal hanging by the ſoldering iron, or a drop of glaſs ſuſpended, undergoes the like contraction and induration; and the preſſure of the atmoſphere is not ſound neceſſary towards the production of theſe effects.

When earthy bodies as arſenic, antimony, zinc; and when all earths in certain combinations, are thrown into vapour or ſublimed by Fire; we are certain their parts are ſevered to a conſiderable diſtance from each other: and when we ſee theſe vapours crowd and thicken as faſt as they cool, and form large particles, the heaps of which are called flowers; or when we ſee the parts of theſe vapours coaleſce, as faſt as the Fire departs from them, and form ſolid bodies called ſublimates, on all parts, as well as on the moſt depending parts of the recipients; we have reaſon to conclude, that the parts of ſuch bodies attract each other to the greateſt diſtances which intercede them in theſe vapours.

In capillary attractions, it is manifeſt that the parts of a tube contiguous to a liquor cannot operate to raiſe the liquor above thoſe parts; and as the parts above the liquor are thoſe which draw it up contrary to its gravitation; theſe parts attract the liquor at a diſtance from them.

If a piece of iron be placed in a ſolution of copper, the iron will draw to itſelf all the copper earth from every part of the liquor, and the earth ſhall be found adhering to the iron in its metallic form: ſhewing that the particles of cupreous matter attract the iron at a conſiderable diſtance, and move towards it when they are ſo poiſed that their gravitation is not prevalent. The ſame inference is to be made from the ſilvering of copper in mercurial ſolutions, or ſolutions of ſilver; and from the gilding of metals by immerſion in ſolution of gold; and from many experiments of the like nature.

The earth in the compoſition of fluor acid, and riſing with it in vapour elaſtic and ſcarcely viſible whilſt air is excluded; when it paſſes into water, and therein depoſits the acid, concretes into a gelatinous maſs, which ſlowly dried becomes ſolid, or into cruſts floating on the water. If the parts of this earth, which in the foregoing ſtate muſt have been diſtant, had no power to attract each other at that diſtance, they might indeed ſubſide ſeverally in the water, but they could not coaleſce as they do, in drying the gelatinous maſſes; or form bubbles incruſted with earth, and piled on each other to the height of half a foot above the water; as it happens, when the elaſtic fluid from fluor is puſhed thro' water.

When a bowl or hollow cylinder of plaſtic clay is formed on the potters wheel, and ſuffered to dry ſlowly, it contracts 1-12th in every dimenſion. In the plaſtic ſtate, when the maſs is ſwelled by the admixture of water, the earthy parts are certainly more diſtant than they are in the contracted ſolid dry body. If theſe parts had no power of attraction capable of acting at a diſtance, the figure of the whole maſs could not be preſerved in drying; for as faſt as the water evaporates they moſt collapſe, according to their gravity; or adhering to each other, their contraction would be in the line of gravity and not horizontally: but as the utenſils thus made, preſerve their form in drying, and contract horizontally, as well as vertically, without fiſſure, the power of attraction of their parts, muſt operate at a diſtance, as well as in the contact of them. The like inference may be juſtly made from the contraction of ſucculent wood, fruits, kernels, leather, cheeſe and all ſucculent bodies by exſiccation; and from the coiling of paper, parchment, barks and other bodies towards the part ſooneſt dried. For in all theſe inſtances, diſtant parts approach in all directions as well as in that of their gravity, and cohere the more firmly as they are more nearly approximated.

The approximation of bodies placed diſtant and floating on ſtagnant water; and the accelerated motion of theſe towards each other, as they approach nearer; the attraction of mountains, and many other phenomena might be offered as further proofs, that the power of attraction operates on earthy bodies at a diſtance, tho' not ſo forcibly as in the contact of them, nor perceptibly except in certain circumſtances.

When water is expanded by heat, and equably diffuſed in a ſpace 14000 times greater than the volume of the water, and ſuſtains the preſſure of the atmoſphere; and when water is ſtill more expanded by applying the like heat, and averting the preſſure of the atmoſphere, it is evident that the parts of water are removed to a conſiderable diſtance from each other. If theſe parts, ſo far diſtant in hot vapour, or leſs diſtant in clouds, are found to ruſh together when the heat is removed, which happens in diſtillations, in dew, rain, hail, ſnow, may we not infer, that all the ultimate parts of a drop of water, falling from on high, attract each other, at the greateſt diſtances which intercede them, when ſuch parts form vapour or clouds; and that as they attract at ſmaller diſtances they attract at greater diſtances? And as the power of gravity tends only to draw the particles of a louring cloud to the earth, ſeverally and in ſucceſſion; and as the drops which fall to the earth, from the higheſt clouds, are the largeſt, whether the atmoſphere be troubled with winds or not; is it not thence to be inferred, that the particles and the drops of water attract each other during the whole time of their deſcent? May it not be queſtioned whether water, falling from the higheſt regions of the clouded atmoſphere, would not meet the earth in much larger drops or in cataracts, were not the attractive powers of the drops counteracted by their electrical atmoſpheres.

As the phenomena of condenſations are very different from thoſe which ought to reſult from the gravitation or the motion of the parts of water, in vapours raiſed from water, or in clouds wafted in the air; and as theſe phenomena are ſuch as are naturally deducible from the reciprocal attraction of the diſtant parts of water; on our conſideration of theſe only, we apprehend that theſe parts attract each other at various diſtances of them. But for the reaſons formerly given, the riſe of water in ſnow or between plates of ice, and the bending of ice, and the approach of diſtant pieces of ice towards each other, in water, are conſiſtent evidences, proving that the parts of water attract each other at various diſtances between them.

The like obſervations may be made concerning the attraction of earth to water, and the mutual attractions of theſe and acid and alkali and air, and concerning the other ſimple attractions; and by the ſame way of reaſoning on theſe, it will appear that the power of attraction operates on their parts, at various diſtances of them. For when theſe parts are thrown aſunder and are widely diſtant from each other, they approach as faſt as the power which diſperſed them ceaſes to act; they form ſolid ſublimates, as fire is withdrawn from them, and cryſtals or other ſolid concretes, as menſtrua are withdrawn from them; and they draw towards each other in all directions, as well as in that of their gravity. We moreover find a capillary attraction of bodies conſiſting of theſe different kinds of matter: and theſe bodies are flexible in different degrees; and the parts of them, however diſtant in menſtrua, are drawn from every part thereof, into a body placed therein; and their parts are daily drawn from afar in the atmoſphere, which is impregnated with them, until they are attached to bodies, forming combinations or cauſing decompoſitions.

Omitting the obſervations which, by reaſon of their ſimilitude to theſe already made, will readily occur to the reader, and will ſhew that any parts of matter, as well as thoſe of earth or water, which attract each other in the contact of them, do attract at different diſtances of them: I ſhall, by a few inſtances, ſuggeſt to him the further proofs of the truth of this notion.

The parts of the elaſtic fluids muſt be diſtant from each other by ſeveral hundreds of their diameters, even when theſe fluids are compreſſed by the whole weight of the column of the atmoſphere which they bear. And although it may be ſaid, that on mixing elaſtic fluids the parts are moved towards each other, ſo as to come in contact, yet the molecules ſo formed could not concrete into maſſes, if the parts thereof did not attract each other at a diſtance.

When the acid and alkaline elaſtic fluids are preſented to each other, their diſtant parts are drawn together, and form a body, the volume of which is not a 1000th or perhaps not the 10000th part of that of the elaſtic fluids. In every inſtance of this kind, it is apparent that the parts, which attract each other, do attract at different diſtances between them; whether this diſtance be ſmall, as it is when we uſe fluids compreſſed by the atmoſphere; or greater, as it is when we remove from the fluids half the preſſure of the atmoſphere; or ſtill greater, as it muſt be when we avert greater parts of the preſſure of the atmoſphere. As the elaſtic alkaline fluid and fixable air act thus on each other; and the elaſtic fluid called inflammable air is in like manner affected by the alkaline elaſtic fluid: It appears that the parts of all theſe fluids attract each other at double, triple, quadruple or greater diſtances; and that they run together from the greater diſtances as well as from the ſmaller. The diſtant parts of alkali diffuſed in air are drawn into oil of vitriol: the diſtant parts of acid diffuſed in air are drawn into the ſolution of ſalt of tartar: the diſtant parts of water ſuſpended in air, are drawn into oil of vitriol or ſalt of tartar : the diſtant molecules of fixable air, diffuſed in air, are drawn into ſoap-lees, or lime-water, or lime : The diſtant parts of Phlogiſton diffuſed in air or menſtrua, are drawn to metallic calces. In theſe and ſimilar inſtances, we perceive that all the parts of matter, which are capable of cohering, do attract each at every diſtance to which we can trace them.

Thoſe who conſider the particulars to which theſe ſummary obſervations relate ; and who know that attractive powers decreaſe in a duplicate, if not in a higher ratio of the diſtances between the bodies ; and who obſerve how the powers, which tend to draw diſtant particles together, are counteracted by the gravitation of the particles, or by the tenacity of fluids interpoſed between them, or by repellent matter adhering to them, or by fire interceding them ; and who conceive that attractive powers, as well as other powers, may act, where they produce no motion or viſible effect, by reaſon of their counteraction ;

action; will find that all parts of matter, which attract in the contact of them, do attract at ſundry diſtances of them, with abated force, *eſpecially when theſe parts are poiſed and at liberty to turn their friendly poles, if they have polarity, towards each other.*

On this occaſion I forbear the mention of the electric fluid, not becauſe there is reaſon to queſtion whether it attracts bodies at conſiderable diſtances, and with forces abated, whilſt the diſtances are encreaſed; but becauſe I cannot ſpeak of it with preciſion.

Seeing then, that the parts of all the elements, except Light, which is elſewhere to be conſidered, are endued with the power of attraction, which in many inſtances is found to extend to ſmall diſtances with conſiderable force; in other inſtances is found to extend to greater diſtances, but with a force inferior to that of the gravitation of theſe parts; and in other inſtances evidently operates at the greateſt diſtances to which the parts are removed from each other, or at which they can be retained in veſſels and examined; we may conclude that the powers of theſe attractions extend to much greater diſtances; and as we have no reaſon for believing that they ceaſe, at any aſſignable interval of time or ſpace; whilſt the power of gravitation is acknowledged to extend to the utmoſt limits of the univerſe; and as it is probable that the power of gravitation conſiſts of theſe ſimple attractive powers; it may be truly ſaid, that the parts of bodies which attract mutually, in the contact or at any ſmall diſtances of them, do attract at the greateſt poſſible diſtances between them; eſpecially when they are at liberty to preſent their friendly poles towards each other, if they have polarity.

Notion XVI.

Atoms which repel each other to the ſmalleſt Diſtances between them, or at any Time, do repel to all Diſtances, and at all Times.

Illuſtration.

BY various well known experiments we are convinced that the parts of air however cloſely approximated by mechanical agency, tend to recede from each other, or do repel with immenſe force. And if air ſo compreſſed, do not always reſume its former volume, when the preſſure is removed; this does not indicate that the power of repulſion is impaired by keeping the parts of air for a long time cloſely approached to each other; but is to be attributed to other cauſes; the moſt general of which are, the eſcape of air through wet leather, which can reſiſt the paſſage of air only with a power equal to that wherewith it holds water in its cells or pores; ſecondly the abſorption of air into the fluids or bodies which reſiſt its expanſion; and laſtly, the admixture of phlogiſtic matter, which being detached from condenſing veſſels of the metallic kind, is capable of weakening the elaſticity of the air: that is to ſay, it is capable of counteracting the repulſion which is the cauſe of the elaſticity of air. We are in like manner ſatisfied that the parts of air, which are further diſtant from each other, as they are, when air is compreſſed only with the force of two atmoſpheres, do repel each other with conſiderable force; and that this force is notable at greater diſtances, as in atmoſpheric air.

When we conſider that the valves of an air pump cannot be moved without ſome force, and that the rarified air in the receiver muſt expand with a force ſuperior to the reſiſtance of the valves, ſo long as this inſtrument operates towards exhauſting the receiver; we learn that the parts of air repel each other with notable force, at the greateſt diſtances of them, in which they can be ſubmitted to experiment. The height and condition of the atmoſphere further ſhew, that the power of repulſion operates at all times, and at all known diſtances of the parts of air; and there is no reaſon to imagine that it ceaſes at any time or diſtance; although its effects do ceaſe by counteraction; as when, in the upper ſurface of the atmoſphere, the repulſive power of the atoms is, by reaſon of their diſtance, exceedingly weak and preciſely equal to their gravitation; or when the repulſive power of the parts of air, is counteracted by the attractive force of other interpoſed atoms, and the air is thus condenſed, ſo as to form a part of the maſs of inelaſtic fluids, as water, or of ſolid bodies, as *mercurius calcinatus*, *minium*, &c.

When the obſervations and experiments whereby we prove that the parts of air repel in the manner expreſſed, are made on the acid, alkaline, and phlogiſtic matter; when we ſee theſe, detached from bodies, burſting veſſels, compreſſible, expanding indefinitely, until counteracted by gravity or other means; we neceſſarily conclude that the homogeneal parts of theſe, as well as thoſe of air, do exert a power of repulſion at all times and at all diſtances; the force of which repulſion is in a ratio not widely different from the reciprocal ratio of the diſtances between the centers of the atoms: and further conclude, that altho' the power of repulſion produces no ſenſible effect towards removing atoms from each other, when they are drawn together by a more forcible power of intermediate atoms; this power of repulſion doth nevertheleſs perſiſt when it is ſeemingly ineffectual, as well as when it produces the moſt ſtriking effects; for it cannot be reaſonably preſumed that this power is annihilated by combination, and created again by the mere decompoſition of bodies.

Thus it is to be underſtood, that the powers which actuate matter, are not confined in time or ſpace, nor commutable, nor deſtructible: but that their effects are modified, and limited to certain times, occaſions, and ſpaces, by their mutual counteractions; and thus we may correct the wrong impreſſions made by ſome expreſſions, and chiefly by falſe conceptions of the following paſſage, in the thirty-firſt Query in Sir *Iſaac Newton's* Optics, page 370, "Since metals diſſolved in acids attract

“ but a ſmall quantity of the acid, their
“ attractive force can reach but to a ſmall
“ diſtance from them. And as in Algebra,
“ where affirmative quantities vaniſh and
“ ceaſe, there negative ones begin; ſo in Mechanicks,
“ where attraction ceaſes, there a
“ repulſive virtue ought to ſucceed. And
“ that there is ſuch a virtue, ſeems to follow
“ from the reflexions and inflexions of the
“ rays of light. For the rays are repelled
“ by bodies in both theſe caſes, without the
“ immediate contact of the reflecting or inflecting
“ body. It ſeems alſo to follow from
“ the emiſſion of light; the ray, ſo ſoon as
“ it is ſhaken off from a ſhining body by the
“ vibrating motion of the parts of the body,
“ and gets beyond the reach of attraction,
“ being driven away with exceeding great
“ velocity. For that force which is ſufficient
“ to turn it back in reflexion, may be ſufficient
“ to emit it. It ſeems alſo to follow
“ from the production of air and vapour.
“ The particles when they are ſhaken off
“ from bodies by heat or fermentation, ſo
“ ſoon as they are beyond the reach of the
“ attraction of the body, receding from it,

" and alſo from one another with great " ſtrength, and keeping at a diſtance, ſo as " ſometimes to take up above a million of " times more ſpace than they did before in " the form of a denſe body. Which vaſt " contraction and expanſion ſeems unintel- " ligible, by feigning the particles of air " to be ſpringy and ramous, or rolled up " like hoops, or by any other means than " a repulſive power. The particles of fluids " which do not cohere too ſtrongly, and are " of ſuch a ſmallneſs as renders them moſt " ſuſceptible of thoſe agitations which keep " liquors in a fluor, are moſt eaſily ſeparated " and rarified into vapour, and in the lan- " guage of the chymiſts, they are volatile, " rarifying with an eaſy heat, and conden- " ſing with cold. But thoſe which are " groſſer, and ſo leſs ſuſceptible of agitation, " or cohere by a ſtronger attraction, are not " ſeparated without a ſtronger heat, or per- " haps not without fermentation. And " theſe laſt are the bodies which Chymiſts " call fixed, and being rarified by fermen- " tation, become true permanent air: thoſe " particles receding from one another with

“ the greateſt force, and being moſt diffi-
“ cultly brought together, which upon con-
“ tact cohere moſt ſtrongly. And becauſe
“ the particles of permanent air are groſſer,
“ and ariſe from denſer ſubſtances than thoſe
“ of vapours, thence it is that true air is
“ more ponderous than vapour, and that a
“ moiſt atmoſphere is lighter than a dry
“ one, quantity for quantity. From the
“ ſame repelling power it ſeems to be that
“ flies walk upon the water without wetting
“ their feet; and that the object-glaſſes of
“ long teleſcopes lie upon one another with-
“ out touching; and that dry powders are
“ difficultly made to touch one another ſo
“ as to ſtick together, unleſs by melting
“ them, or wetting them with water, which
“ by exhaling may bring them together;
“ and that two poliſhed marbles, which by
“ immediate contact ſtick together, are dif-
“ ficultly brought ſo cloſe together as to
“ ſtick.”

NOTION XVII.

The mutual Attractions and Repulſions of the Atoms of Matter, are more forcible in the ſmalleſt Diſtances, than in any greater Diſtances between them.

Illuſtration.

THIS notion, ſo far as it relates to attraction, is not controverted, and the proofs of it may be gathered from the foregoing pages. I do not mention the ratio in which attractive forces are reciprocally as the diſtances between the attracting corpuſcules; becauſe I am not ſatisfied about it. For it doth not appear that the different parts of matter attract each other with equal forces; or that all the forces are equal at equal diſtances of the parts; or that they decreaſe all alike, as the diſtances increaſe, in the ratio aſſigned to gravitation by *Newton*, or in the higher ratio of the diſtances, expreſſed in Prop. 85, Book I. of his *Principia Math.*

where he has a view to coheſion and magnetiſm. And as it is not probable that the parts of bodies attract each other with equal force, in every poſition of them relatively to each other; ſince obſervations, of which I ſhall preſently mention a few, indicate the contrary; ſo it is not probable that their attractive forces do, in all circumſtances, decreaſe in any one reciprocal ratio of their diſtances.

It is univerſally known that the parts of air repel each other more forcibly, as they are more nearly approached towards each other: and by reaſoning on the experiments which ſhew the ſpaces into which air is compreſſed by different forces, *Newton* concludes that the repellent forces of the parts of air are reciprocally proportional to the diſtances of their centers; ſuppoſing the denſity of air to be as the compreſſion. Although pure air has not yet been examined; this may be conſidered as a cloſe approximation to the true rate of this repulſion.

By experiments ſimilar to thoſe whereby the rate of repulſion of the parts of air have been eſtimated, we found, during the late courſe of experimental enquiries, that acid matter, which expands and frequently burſts the recipients when unpractiſed chemiſts detach it from compounds incloſed in tight veſſels, reſiſts compreſſion nearly in the ſame manner as atmoſpheric air doth, and the alkaline elaſtic fluid ſubmitted to the like examinations, was found to conſiſt of parts which repel each other with forces which are not much different from thoſe of the common air.

As all veſſels are permeable to phlogiſton, when it appears in the character of fire, which it never fails to do when it is detached from earthy, alkaline, acid and aerial matter, we cannot yet determine in what proportion of their diſtances the parts of this element repel each other. It ſeems, however, that they repel each other more forcibly at the ſmaller than at the greater diſtances of them, ſo that phlogiſton is not an exception to the foregoing notion. For fire is known to expand the more forcibly and quickly, by how much the quantity of fire is greater in a given ſpace; the intenſity of every combuſtion, and the effects of all furnace fires in expanding, penetrating and vaporating bodies, being found greater or leſs, as the quantity of phlogiſton, diſengaged from fuel in a certain time and ſpace, is greater or leſs. And whether fire conſiſt of phlogiſton only, detached from groſſer matter; or of phlogiſton combined with, and condenſing Light; theſe phenomena indicate the repulſive forces of the parts of Phlogiſton to be inverſely as the diſtances between them, in a duplicate or ſome other ratio, to be hereafter diſcovered. And the ſame thing may be inferred from the part which it acts in exploſions, and from divers analogies which it bears with the groſſer elaſtic fluids.

We ſhall hereafter ſhew that this notion is applicable to Light as well as to the repellent parts of the fluids already mentioned. And thoſe who conſider the electric fluid as an element diſtinct from all others, will readily admit, that the parts thereof repel each other more forcibly, when they are nearly approached to each other, than when they are far diſtant from one another; ſince they otherwiſe could not tend to preſerve the equilibrium which this fluid is known to affect, in the vicinity of any body; neither could the electric fluid, conformable to any other known law, expel from the exterior ſurface of the Leyden phial, as much electric matter as is ſurcharged on the interior ſurface thereof; neither could this fluid, when we attempt to crowd it, beyond meaſure, on one of theſe ſurfaces, ruſh rapidly to the other ſurface, or be ſo rapidly conveyed by conductors to the parts at which it is deficient, as we experience in the common practice of electricians: Neither could the electric atmoſphere of a body electrified *plus*, be more denſe near the body where we take a vigorous ſpark, than at a diſtance from the body, where we draw away the electric atmoſphere, or a part thereof, ſilently.

If the repulſive power of magnets were to be reckoned amongſt the ſimple repulſive powers; we might obſerve that magnetic repulſion is conformable to the foregoing Notion;

tion; but to perceive this conformity, we muſt attend to the attractive, as well as to the repulſive powers of the magnetic bodies.

The chief uſe of theſe Notions, in our intended enquiry concerning Light, will appear, when we come to conſider the mutual actions and relations of Light and groſſer bodies; and when we attempt to explain the Optical Phenomena, without aſſuming any property or paſſion or motion of Light, which is not demonſtrable, or analogous to properties, paſſions, or motions of other kinds of matter. Such of theſe notions as are indiſputable will be uſed as axioms; and others which are not ſufficiently eſtabliſhed, ſuch as that is, concerning the attraction of Phlogiſton to air, will be applied cautiouſly, and only when we reaſon from analogy; which ſort of reaſoning is not, by itſelf, concluſive.

SECT. X.

Of Gravity and Denſity.

THE inceſſant, indefeaſible ſimple attractive powers, which actuate the atoms of matter, whether they be diſtant or in contact; muſt neceſſarily actuate bodies compoſed of theſe atoms, and the terraqueous globe compoſed of ſuch bodies; and muſt tend to approach them towards each other, with the different forces which they exert at the different diſtances between them: and the ſame attractive powers, muſt either co-operate with another power, which is that of gravity; or the power of gravity is compoſed of theſe ſimple attractive powers, and of nothing more. But that the power of gravity conſiſts of theſe only, appears to me, on divers conſiderations, of which I ſhall mention a few that are the moſt eaſily expreſſible.

Since the powers, by which the ultimate parts of bodies attract each other, muſt be active in the gravitation of the bodies: ſince the attractions of the ultimate parts are thoſe which we trace under the name of ſimple attractions: and ſince the ſum of the powers which cauſe the coheſions, combinations and relative motions of the parts of bodies, is amply ſufficient to draw the bodies conſiſting of ſuch parts, towards the earth, with all the force which we call their weight: we have no reaſon for ſuppoſing that bodies gravitate by ſome power totally different from thoſe which cauſe combinations and aggregations, except that which is ſuggeſted by *Newton*.

He ſhews in Prop. 85, *lib. prim. Princip. Math.* "Si corporis attracti, ubi attrahenti "contiguum eſt, attractio longe fortior ſit, "quam cum vel minimo intervallo ſeparan"tur ab invicem: vires partularum trahen"tis, in receſſu corporis attracti, decreſcunt "in ratione pluſquam duplicata diſtantiarum "a particulis." The parts of ſeveral bodies being found to attract each other more forcibly when they touch, than when they are ſeparated by the ſmalleſt perceptible interval; and the forces wherewith they attract, appearing to decreaſe in a triplicate or higher ratio of their diſtances; while the force of gravity decreaſes only in the duplicate ratio of the diſtances of gravitating bodies; it is generally inferred that bodies gravitate by an agency totally different from that which cauſes combination or aggregation. But this inference is to be rejected: becauſe, in the argument, no notice is taken of the repulſive forces exerted between gravitating bodies at all diſtances of them, and counteracting the attractive powers, as it will further appear in the 12th Section; becauſe no account is taken of the manner and rate in which the attractive forces are varied, as the parts of bodies preſent to each other different faces; of which variation I ſhall take ſome notice in the next ſection: and becauſe in arguing from effects to the powers which cauſe them, the concluſions cannot be true; when we neglect the direction of theſe powers, the circumſtances in which they are varied; and the reſiſtances which they meet, from other inceſſant powers acting on the ſame bodies.

In all circumſtances, except thoſe wherein the parts of bodies are arranged in a certain order relatively to each other, the forces wherewith the bodies attract each other, correſpond with the forces wherewith they are attracted to the earth; notwithſtanding that maſſes, which gravitate ſtrongly, do not draw towards each other with any ſenſible force, even at the ſmalleſt perceptible diſtances of them. For if we take two equal globes of lead as inſtances, each of theſe gravitates with a force, which is the ſum of the ſimple forces exerted between all the attractive parts of the globe of lead and thoſe of the whole terraqueous maſs; whilſt the globes of lead can attract each other, only with a force, which is the ſum of the forces of their attractive parts: and altho' the gravitation of lead be really effected by the primary powers only of attraction, the gravitation of each globe of lead, at any given diſtance of its centre, from the centre of the earth, ought to exceed the force wherewith the leaden globes mutually attract at the like diſtances of their centers from each other, as much as the attractive parts of the whole earth and the one globe of lead, exceed in number the attractive parts of the two globes of lead: admitting that there is no matter, in the terraqueous maſs, which attracts the parts of lead more, or leſs forcibly, than theſe parts attract each other: and as the centers of two globes of lead, are conſiderably diſtant, when their ſurfaces come near to touch, two ſuch maſſes, each of which weighs a pound, ought not to attract each other with a force equal to the ſmalleſt weight which we can diſcriminate by the niceſt inſtruments; altho' their gravitation were to ceaſe during the experiment. Much leſs ought their attraction to each other to be ſenſible when they are pendulous by a thread, from a fixed point; becauſe they cannot approach each other, without moving contrary to the direction of their gravitation, and overcoming the friction or other reſiſtance, at the point of ſuſpenſion; and when they are mechanically poiſed, in any other manner, friction more ſtrongly reſiſts their approach; and if they are poiſed in a fluid, like water or mercury, the tenacity of the fluid reſiſts their approach towards each other. Neither ought maſſes of matter, much larger and heavier than theſe, to attract each other, with a force diſcoverable by the means of any inſtrument hitherto deviſed; although it were admitted, that no elaſtic fluid, forming a ſmall atmoſphere round each of them, impedes their approach towards each other, when the diſtance between them is ſmall.

It is further to be conſidered, that as the forces of the ſimple attractions are different, with regard to different ſorts of matter; and as there are numerous gradations of theſe forces: if the gravitation of a body were not effected by theſe ſimple powers, and if it were effected by ſome different power; we ſhould not find a correſpondence in all caſes, between the ſum of theſe ſimple forces, and the gravitation of any given body. But a correſpondence of this kind is obſervable, in all gravitating bodies, as well as in any one which I mention for the ſake of example. The following ſimple attractive powers tend to draw any maſs conſiſting chiefly of earthy matter, towards the terraqueous globe.

The power whereby earth ſtrongly attracts earth: the power whereby earth ſtrongly attracts acid: the power whereby earth attracts phlogiſton: the power whereby earth attracts alkali: the power whereby earth attracts water. Thus we reckon that every kind of matter, of which the terraqueous globe chiefly conſiſts, attracts an earthy body: and as the ſorts of groſs matter, which attract it moſt powerfully, conſtitute the greater part of this our planet; the ſum of the ſimple attractive powers, which draw a ſuſpended or projected earthy body towards the ſurface of our planet, muſt be great. Conſidering water in the next place; we find that water attracts acid leſs forcibly than earthy bodies attract acid; becauſe acid will forſake water to unite with earthy matter, and becauſe an ounce meaſure, or an ounce by weight of earth, will hold as much acid matter concentrated, as can be held by a much greater quantity of water: and water appears to attract alkali leſs forcibly than earth attracts alkali; becauſe the union of earth with alkali in the fixed alkalies, and in alkaline glaſſes is much more firm than the union of water and homogeneal alkali, in the cauſtic volatile alkali : and the attraction of water to Phlogiſton, if ſuch an attraction doth exiſt, is incomparably weaker than the attraction of earth to Phlogiſton : and the attraction of water to water, is weaker than the attraction of earth to earth ; as it appears in the aggregate of theſe : and the attraction of water to air, is confeſſedly weak, in compariſon with any of the primary attractions of earth : and without attempting any accurate eſtimations, we readily perceive, that the ſum of theſe ſimple forces, is much ſmaller than the foregoing ſum of the attractive forces of earthy matter : and water and earth, endued with no attractive powers, ſave thoſe our ſimple powers, which cauſe combinations and coheſions and capillary attractions, ought to gravitate differently : a meaſure of the denſeſt watry body ought to gravitate with much leſs force, than that wherewith an equal meaſure of the denſeſt earthy body gravitates. But as they are found to gravitate conformably to the foregoing ſimple attractive powers, ſo far as we can eſtimate theſe ; no other power, cauſing gravity, is admiſſible.

Thoſe who would proceed farther, to compare the ſimple attractive forces of other matter with the gravitation thereof; are not to be hurried into a new opinion, when they find that acid, alkaline, aerial and phlogiſtic matter, or bodies compoſed chiefly of theſe, do not gravitate ſo forcibly, as might be expected from the bare conſideration of their ſimple attractions. For it is to be noted, that the parts of theſe bodies are repelled by all the like parts of the terraqueous maſs; and that ſuch bodies can gravitate, only by the exceſs of the attractive, above the repulſive forces. The ſimple attractions of Phlogiſton, are not numerous nor forcible, in compariſon with the primary attractions of earth: moreover, the Phlogiſton of any phlogiſtic compound, is repelled by the whole quantity of Phlogiſton in the terraqueous maſs; and is perhaps repelled by all the watery matter thereof: therefore Phlogiſton ought, by our ſimple powers, to gravitate very weakly, or not at all; although it is manifeſtly attracted by the earthy and acid matter of the terreſtrial globe. And we accordingly find that compounds, conſiſting chiefly of

Phlogiſton and other repellent matter, are much lighter than compounds conſiſting of any other repellent matter, beſides Phlogiſton; although the former and latter compounds be equal in volume; and appear in every trial to be nearly equal in denſity. Let the compariſon be commenced between camphor and ſal ammoniac; and be carried on between the combuſtible and the incombuſtible bodies, which contain the leaſt of earth or water.

Any man, who knows that reſin conſiſts chiefly of phlogiſton and acid, and that it contains very little earth or water; altho' he had never weighed reſin, might conclude from what we have briefly ſuggeſted, that its ſpecific gravity muſt be much leſs than that of a ſtone or a metal, even when the void ſpaces in theſe bodies are equal. But philoſophers, who generally conſider the power of gravity, as a thing different from all other attractive powers; and who imagine that it acts equally on all kinds of matter; impute the difference of ſpecific gravity,

vity, to the different denſities of bodies: and thus, a cubic inch of gold, is ſuppoſed to contain about ſixteen times more gravitating matter, than is contained in a cubic inch of reſin. It might be expected, that an opinion ſo prevalent, is ſupported by experiments and obſervations, directly proving that reſin is ſixteen times more porous than gold. But nothing is done to this effect: and all the obſervations hitherto made, indicate, contrary to that prevalent opinion, that bodies, which have not a tenth, or fifteenth, or twentieth of the ſpecific gravity of gold, are no more porous nor compreſſible than gold is. In the *Newtonian* ſchools, we are indeed taught to judge of the quantity of matter in a body, by its inertia, and by its momentum compared with its velocity: and ſince the force, neceſſary to move a globe of gold with a certain velocity, is much greater than the force neceſſary to move an equal globe of reſin, with the ſame velocity; the globe of gold muſt conſiſt of a much greater quantity of matter than is in the globe of reſin, provided the inertia of bodies be as their quantities of matter. But it is to be well conſidered, that the inertia of bodies, whether in reſiſting a change of their ſtate of reſt to a ſtate of motion; or in reſiſting a change from their ſtate of motion, with equal velocity, to a ſtate of reſt; is as the gravity of the bodies, indubitably: and that the gravity of the bodies is not, experimentally, as their quantities of matter, unleſs they conſiſt of the ſame kind of matter: and that the legitimate concluſions to be made from the inertia and momentum of bodies, relate to their gravity and not to their quantities of matter. This curſory obſervation is ſufficient for our preſent purpoſe; and may, perhaps, excite diſpaſſionate philoſophers to reviſe ſeveral important parts of the doctrines of the modern ſchools.

Although the limits, to which I am confined, do not permit me to expreſs fully, and to inforce theſe notions of gravity and denſity; I flatter myſelf, that the philoſophic reader, guided, in ſome meaſure, by the faint lights which I have endeavoured to throw on theſe ſubjects, will readily perceive; that we are not authoriſed, by experience,

rience, to affirm that all bodies gravitate in the direct ratio of their quantities of matter, or that our ſimple attractive powers are inſufficient for the gravitation of bodies; and that the notions of gravity and denſity, which I have propoſed, ought to be adopted, until they are contradicted by experiments; becauſe theſe notions only, accord with, and enable us to explain, divers phænomena already mentioned; without our aſſuming any degree of poroſity, which is improbable and contrary to our experience of bodies ſpecifically light; and without our aſſuming a material agent or any power, to cauſe gravitation, different from the powers which are manifeſtly active in almoſt all the natural operations: and he will perceive that theſe obſervations and arguments, afford concluſions, to the following effect.

I.

The abſolute gravity of an *homogeneal* body, is directly as the number of its ultimate parts.

II. The

II.

The ſpecific gravity of an *homogeneal* body, is directly as the number of ultimate parts contained in a given ſpace.

III.

The denſities, of different bodies, cannot be truly deduced from the ſpecific gravity of them, unleſs the bodies be compoſed of the ſame kinds of matter.

IV.

The abſolute gravity, of compounded bodies, is not directly as the number of their ultimate parts, or as their quantities of matter: for the abſolute gravity of theſe bodies is, Firſt, as their number of homogeneal parts which gravitate moſt forcibly; and again, as their number of homogeneal parts, which gravitate with the weakeſt force; and again, as their number of homogeneal parts which gravitate with intermediate forces. So that the abſolute gravity of compounded bodies, may, in the freedom of ſpeech, be ſaid to be in the compound ratio of the quantities of matter, and of the kinds of matter of ſuch bodies.

V.

The ſpecific gravity of a compound body, is in the like ratio, of the quantity and kinds of matter, contained in a given ſpace.

VI.

Specific gravity, and *denſity*, ought no longer to be uſed as commutable terms.

VII.

Bodies, whoſe ſpecific gravity is comparatively ſmall, may alter the direction of the rays of Light, by reaſon of their denſity; as much as is done by bodies, whoſe ſpecific gravity is comparatively great, by the like reaſon of their denſity.

VIII.

As the parts of earth gravitate more forcibly than thoſe of water, and theſe gravitate more forcibly than the parts of alkali, and theſe gravitate more forcibly than the parts of Phlogiſton ; it is conſiſtent with the tenour of nature that the parts of Light ſhould gravitate more or leſs forcibly than any of the foregoing parts ; and if the forces wherewith Light is repelled from certain parts of the terraqueous maſs, be equal to the forces wherewith Light is attracted by other parts of the terraqueous maſs ; or if theſe forces be nearly equal ; Light may, in conformity to laws, ſuch as thoſe which govern other kinds of matter, gravitate very weakly, or it may not gravitate, although it may attract certain parts of the terraqueous maſs : and moreover, it is not to be preſumed that Light doth gravitate, until ſome proof of its gravitation can be produced. This latter ſubject will come under conſideration, when we treat expreſsly of Light.

SECT XI.

Curſory Remarks on Aggregation, on the ſeveral compound Attractions; on Polarity and Magnetiſm; and on the objections which may be raiſed againſt the foregoing Notions.

WHAT I have already ſaid is ſufficient to ſhew, that no agent or power different from our ſimple attractive power, is neceſſary towards the elective attractions, and the compound elective attractions, and the ſeveral combinations and decompoſitions noticed by the Chymiſts, or effected in the great elaboratory of Nature. And I need only obſerve further, that the force of theſe attractions is not to be eſtimated in any inſtance, from the motion or conflict which enſues after we mix certain bodies; becauſe this is owing to the eſcape of elaſtic matter, and not to the violence wherewith the parts ruſh towards each other; as it was imagined about the time when Sir *Iſaac Newton* wrote.

Towards explaining the phenomena of capillary attraction, no other power, beſides our ſimple attractive powers, is to be ſuppoſed. For the ſimple attractive powers which actuate earth and water, are manifeſtly ſufficient to cauſe the aſcent of water in tubes or between planes of glaſs or earthy matter, or in the interſtices of ſpongy bodies, or in the ſpaces in heaps of ſand or in any earthy powder: and it is the forcible aggregation of earthy bodies, that prevents their diſſolving in, or combining with the water, and which limits the effect of the powers which draw earth and water towards each other, to the mere contact of the water with the ſurfaces of ſuch earthy bodies: and the gravity of water manifeſtly limits the aſcent thereof in ſpongy bodies, ſands, and capillary tubes. For ſuch capillary attraction is moſt forcible in thoſe bodies, which are compoſed of elements which ſtrongly attract water, as in earth and ſaline bodies; and it is weakeſt in the bodies which contain but a ſmall quantity of ſaline matter relatively to this quantity of Phlogiſton. And water riſing in ſugar and ſaline bodies, by capillary attraction, diſſolves them; and it riſes between planes cloſely approached, or in narrow tubes, higher than between more diſtant planes, or in wider tubes. And if the heterogeneous parts of oils, ſpirits, mercury, or of any other fluid, and the ſimple attractions of theſe, to the parts of other bodies, are in the like manner conſidered; it will appear that every phenomenon of introſuſception, capillary attraction, wetting, and coheſion of plates by the interpoſition of a fluid, and every amalgamation, correſponds with theſe ſimple powers of attraction, and is cauſed by them; and that nothing except the forcible aggregation, prevents the combination or ſolution of bodies in thoſe fluids which they draw, or adhere to, in the manner already expreſſed. The reaſon why bodies cohere by means of an interpoſed fluid, with a force greater than that wherewith they gravitate: and why fluids riſe by capilary attraction, contrary to their gravity; and why all aggregates are not diſſolved by the liquors which they attract; will appear when we conſider the polarity of the ultimate parts of matter.

Although I have not attempted to determine whether the electric fluid be an element, or a compound formed of parts of our elements; I have frequently remarked, that the electrical phenomena, afford no objections againſt the foregoing Notions of attraction; and that they only indicate that this fluid hath powers of attraction peculiar to itſelf; by the ſame rule that other elements or compounds exert powers of attraction peculiar to themſelves reſpectively. And I flatter myſelf, in conſequence of the opulence and abilities, and the rapid ſucceſs of the gentlemen who are now engaged in this ſubject, that the time is not far diſtant, wherein we ſhall be informed of the nature of the electric fluid, and of its ſimple attractive powers; and ſhall find that the attractions of electric matter to compound bodies, are conformable to the ſum of the ſimple attractions thereof.

Amongſt the notions concerning the ſimple attractions, I ought perhaps to have introduced another, touching a law called polarity, which governs all theſe attractions; for the introduction of this notion would have have enabled me to illuſtrate the others much bettet than I have done; and would have aſſiſted me in ſhewing more clearly that the power of gravitation conſiſts of the ſimple attractive powers which cauſe coheſions, aggregations, combinations and decompoſitions. But thinking it more adviſeable to confine myſelf, in the foregoing ſections, to the doctrines which may find admiſſion, without offering much violence to the preconceived opinions of modern philoſophers; I reſerved the conſideration of the polarity of matter for this place, wherein this polarity ſhall be noticed, chiefly with a view to the objections which may be raiſed againſt the foregoing notions of attractions, by reaſon of aggregation or magnetiſm; and wherein I ſtudy rather to excite enquiry, than to enforce any doctrine, on which I would lay a ſtreſs, during our inveſtigations of Light.

I am of opinion, that all ſimple attractions are more forcible in one direction, or axis of each atom, than in any other; and, that all matter hath this polarity of its parts; unleſs we except Light, to which I neither aſcribe, nor deny this law of attraction, at preſent. My reaſons for this opinion are derived from a multitude of obſervations, of which the following are a ſpecimen.

As a magnetic needle, by reaſon of its gravitation, cannot point north and ſouth, until it is poiſed in a fluid, or in the manner of the mariners compaſs; and as the polarity is manifeſt and effectual, only when the counteraction of other powers is prevented: ſo when the ſevered parts of earthy bodies are poiſed by menſtrua, or fire, or any other means; and when, in this condition of the parts, neither aggregation nor gravitation can counteract their tendency to turn towards each other the faces or poles, in which they may attract moſt forcibly; then we find theſe parts to draw each other, and to cohere moſt forcibly. And neither nature, nor art, furniſhes one inſtance, that I can recollect, of a body, which reſiſts the ſeparation of its parts with notable force, formed in any other circumſtance; or any inſtance of bodies moved or cohering, contrary to the direction of their gravitation, by any attractive force, unleſs one of the bodies be ſoft or fluid, ſo that the parts thereof may freely turn, to the other attracting body, thoſe faces of them, by which they attract it moſt powerfully.

When we compare the precipitates haſtily made from ſolutions of earths, or the crumbling maſſes of theſe haſty precipitates that are quickly dried; with the ſolid aggregates formed by the like earthy matter ſlowly depoſited, or with any fine precipitate ſlowly dried: as when we compare the precipitate of *liquor ſilicum* ſuddenly made by an acid, with the ſolid concrete formed when the ſame acid is very ſlowly introduced into *liquor ſilicum*, by expoſing the one to the fumes of the other: or when we compare the crumbling maſs of the fine precipitate of ſiliceous or aluminous earth haſtily dried, with the ſolid maſs of the like precipitate ſlowly dried: when earthy matter, ſuch as the gypſeous or calcareous, is ſlowly depoſited on veſſels of glaſs or potters ware, and is found to adhere thereto, almoſt as firmly as if it were a part of their ſubſtance; and when we compare this, with the precipitates of the like matter haſtily made, and neither coherent in their parts nor adherent to the veſſels: and when ſpars, ſtalactites, and animal and vegetable ſubſtances petrified by the ſlow depoſition of earthy parts from waters in which they were widely diffuſed; are compared with the precipitates quickly made from ſuch waters reſpectively, by quick exhalation or chemical mixtures: we uniformly find that the parts, which have time or freedom to arrange themſelves in any order or direction, do cohere with the greateſt force; whilſt the like parts, in the fortuitous concourſe and contact of them, cohere very weakly, or not ſenſibly.

In the filings or the finer powders of metallic ſubſtances, the attraction or coheſion of the molecules, is ſcarcely ſenſible: but when any of theſe ſubſtances, ſuch as Zinc, Antimony, Biſmuth, Nikel, Arſenic, are vaporated; or when either the metals or ſemi-metals are fuſed ; the parts of ſuch vapours and fluids, being then at liberty to arrange themſelves in any poſition relatively to each other, approach in certain order, as faſt as the fire which cauſed the fluidity is withdrawn, and they cohere with their ſtrongeſt attractive forces. For in the grain of ſuch bodies, and indeed in the grain of numberleſs other bodies, it is manifeſt that the parts thereof are not equally diſpoſed to unite and cohere in any order ; and the force wherewith the parts of a metal cohere, is incomparably greater than that wherewith the contiguous ſurfaces, of poliſhed plates of metal preſſed together, cohere.

The earths of metals, and the earthy bodies which cannot be metallized by any art yet diſcovered, when finely powdered, diſcover only a very weak attraction or coheſion of the parts into which they were divided. But theſe incoherent parts, when the powders are fuſed, ſo that the ſlighteſt force may turn the ſmalleſt parts thereof, coaleſce in certain order, and cohere with great force, forming ſlags and glaſſes.

The polarity is further ſeen in cements. For no glutinous, gummy, reſinous, or earthy mixture, will operate as a cement, in the ſtate of dry powder, or in any other condition, except that wherein the cement is ſoft or liquid ; by the mediation of water, or ſpirit, or oil, or ſome fluid, which may gradually exhale from it. Then only the poiſed parts arrange and cohere very firmly with each other, and with the bodies to be cemented. Vitrifiable powders cannot cohere with a force greater than that wherewith they gravitate ; and they cannot ſerve as a cement for broken veſſels of porcelain, pottery ware, or glaſs, until theſe powders be reduced to a fluid ſtate, by fire. Then their parts cohere with each other and with the pieces to be cemented ; and when the fire is withdrawn, the cement forms ſolid veſſels of the incoherent fragments.

Lime mixed with ſand, or any hard earthy body comminuted, does not form a coherent maſs. To make mortar ſet and bind firmly, and to become ſolid like a ſtone, it is neceſſary that it be watered, until it be ſoft or nearly fluid, and that it be then ſuffered to reſt. For if the materials be ſlightly moiſtened; or if the water of good mortar, be ſuddenly imbibed by dry bricks, or diſſipated by heat; the cement never becomes hard, nor adheres forcibly to the bricks: and it is obſervable, that mortar, which begins to grow ſtiff, ſoon becomes ſoft, by the briſk agitation called chaſing.

When we examine the ſubject attentively, we find that the ſand, in mortar, gives the ſolid baſis which forcibly reſiſts fracture, and is not ſoluble or diffuſible in water, nor contractible during the exhalation of the water; whilſt the calcareous earth, ſuſpended in water, cements the grains of ſand with each other and with the bricks or ſtones employed in building. And if the attraction of the parts of the calcareous earth, to the ſand or ſtones or bricks, were equally forcible in every face or axis of theſe parts; the bare contact, of any of their faces, with the grains of ſand, or with the other bodies to be cemented, ought to afford an aggregate, as firm as the cement of old walls. For it does not appear that old or hardened mortar contains more water than is contained in ſlaked lime and moiſt ſand; of which alone mortar cannot be made: and if any thing is imbibed from the air by mortar, nothing hinders the like from being imbibed by the mixture of ſlaked lime and ſand. But ſeeing that there is no coheſion, in conſequence of ſuch mixture and contact of ſlaked lime and ſand; and that the aggregation is very ſtrong, when the parts of calcareous earth are well poiſed in water blended with ſand, and when the arrangement which they aſſume is not diſturbed by agitation or haſty ſubduction of the water; we learn that the attraction is moſt forcible in certain faces of the parts of calcareous earth, and that they cannot, by any other faces of them, cohere ſo ſtrongly with each other, and with the ſand and ſtones or bricks, as to compoſe a well cemented ſolid maſs.

This polarity is evidenced in divers other cements, of which, plaiſter of Paris is an inſtance. The powder of prepared plaiſter-ſtone or gypſum, ſhews no coheſion of its particles; whilſt the plaiſter, formed with this powder and water, is a ſolid ſtoney maſs. Since the liquid mixture of this powder and water, ſets without any notable loſs of weight, or contraction of its dimenſions, diſcoverable in the experiments which we made on it; we cannot aſcribe the coheſion of the parts thereof, to the mere approximation of them: and ſince the liquid mixture is found incapable of ſetting and acquiring the hardneſs of plaiſter, ſo long as it is violently agitated, without loſs by exhalation; it appears that ſomething, beſides the contact of the parts, is neceſſary towards the aggregation of ſolid plaiſter; and that theſe parts cannot cohere with their greateſt forces, unleſs they touch, or come near to touch, in certain faces or points of them. For if much air is abſorbed by the ſetting quieſcent mixture, which ſuppoſition we have not yet tried, the agitated mixture is ſtill more expoſed to air, and may freely abſorb it.

When the powder of dry clay is compreſſed, the particles thereof cohere with a ſmall force, for reaſons to be mentioned hereafter. The ſame powder metled, or diffuſed in water, and ſuffered to dry ſlowly, ſo that the arrangement which the parts aſſume whilſt the maſs is ſoft, ſhall not be much diſturbed ; acquires, a ſolid aggregation, which encreaſes to a flinty hardneſs, if the dried maſs be ſemivitrified ; in which ſtate, the arrangement, which was diſturbed by the exhaling water, is eaſily reſumed or perfected. This, compared with the friable maſs, which is formed, when, by an haſty diſſipation of the water, the neceſſary polar arrangement of the parts is prevented or diſturbed ; ſhews that the parts aſſume an arrangement when poiſed, which they cannot otherwiſe obtain ; and that in this arrangement or direction only, they can attract each other ſo forcibly, as to form a body capable of reſiſting fracture or diviſion with conſiderable force. Many obſervaions of this kind, may be made by thoſe who are attentive to the manufactories of bricks, porcelain, artificial ſtone, flint powder and paints ; concerning the two latter of which it is obſervable, that if the flat ſtones, between which they are ground, are ſuffered to reſt for a minute ; a much greater force is neceſſary to move them, with the ſmalleſt velocity, than was neceſſary to conſerve their motion, or to encreaſe it conſiderably.

The polarity now under conſideration, likewiſe appears, by the vegetations and regular forms of metallic and earthy compounds, ſlowly depoſited from menſtrua: as in the *arbor Dianæ*, in the bruſh-like cryſtalization of neutral arſenical ſalt, and in divers other inſtances: moreover, it appears in ziment copper, and other depoſitions of virgin-metal, as of ſilver and gold; the parts whereof being diſengaged from menſtrua, and quickly precipitated, form an incoherent powder: but when they are very ſlowly detached in a quieſcent liquor, they coaleſce, and form a ſolid ductile maſs of metal.

A metal applied to glaſs, and ſtrongly preſſed on it, will not adhere firmly to it. But if the metal be rendered ſoft or fluid, by amalgamation, and if it be in this ſtate laid on the glaſs, and if the menſtruum be then ſlowly withdrawn, the metal adheres forcibly to the glaſs. Thus tin, gold, or ſilver, adhere to the further ſurface of looking glaſſes; or to the gilded toilet and drinking glaſſes. And thoſe who conſider theſe adheſions, and the circumſtances neceſſary thereto, muſt perceive that theſe bodies do not cohere with much force, in conſequence of the mere contact of their parts; and that their coheſion is the more forcible, as the parts of any one of them are more at liberty, by reaſon of fluidity, to turn and touch by the faces of them which are moſt ſtrongly attracted.

Tin applied to iron, or copper, or gold, or ſilver, and preſſed on them; and divers allays uſed in ſoldering, preſſed on metals, will not adhere firmly. But, when tin is liquified, and when ſolders are fuſed, they adhere firmly to the metals whoſe clean ſurfaces they touch; and then ſhew the polarity of their parts, for the reaſons often mentioned.

The ſame inferences may be made from the arts of gilding. For heat is neceſſary in gilding metals with the leaf of gold or of ſilver; and amalgamation is neceſſary for gilding, in the manner of *or molu*: and a fluor ſtate of the gilding metals is neceſſary, in the gilding with ſolutions of gold or ſilver: and extreme comminution, together with preſſure, are neceſſary, in the gilding with tinder of a linen rag, which has been dipped in the ſolution of the gold, wherewith a metal is to be gilded.

In gilding with amalgam, it is not to be preſumed that the mercury contributes to the adheſion, otherwiſe than by poiſing the parts of the gold or ſilver. For mercury attracts iron very weakly, in any condition of them; but ſilver, which attracts iron ſo as to allay with it, will not adhere ſtrongly to iron, if they be only preſſed into contact with each other; and mercury is uſed, if I am not miſinformed, in gilding iron with ſilver.

In many ſublimates of earthy bodies, the regular forms and cryſtals; ſuch as the cryſtals of the argentine flowers of antimony, the cryſtals of arſenic, and the webs of pompholix; denote the polarity of the parts of theſe bodies: for if the parts of the riſing vapours, were poſſeſſed of no power to attract each other in certain faces or directions of them, more forcibly than in any other, the forms and arrangements, which we obſerve in ſublimates, could not be ſo different as they are in different ſublimates, and yet ſo regular and uniform as they are, in homogeneal ſublimates made in the ſame circumſtances. The ſame thing may be inferred from the cryſtals and regular forms of compounds conſiſting of earthy and other matter, when theſe compounds are vaporated and condenſed again in ſubliming veſſels: as when the compounds formed with marine acid and divers metallic calces, are ſublimed, forming corroſive ſublimate, butter of antimony, black martial flowers, &c. or when the powder of orpiment is ſublimed: or when the powder of fuſed ethiops mineral is ſublimed, forming long ſlender cryſtals, which are readily ſeparable from each other; whilſt the maſs of them, reſiſts fracture, in the line perpendicular to the length of the cryſtals, with great force.

The polarity now under conſideration likewiſe appears in all the compounds of earthy and other matter, which cryſtalize or acquire a regular arrangement of their parts; whether theſe be previouſly poiſed by water, or mercury, or fire, or other menſtrua: as in the cryſtals, of all metals and earths, depoſited from water; in tin and other metals, ſlowly depoſited from cooling mercury; in the cryſtals of calcined mercury; in the long needle-like cryſtals of crude antimony when the fire has been ſlowly withdrawn from the melted maſs thereof; in the cryſtaline grain of *plumbum corneum*, *luna cornea*; in all matts ſlowly cooled; and in divers ſimilar inſtances, too numerous to be recounted here.

In comparing the dry powders, of all ſubſtances which may be ſublimed, with the ſolid maſſes formed of them in ſublimations; and in comparing the firm aggregation of ſublimates ſlowly raiſed and ſlowly cooled, with the weak aggregation of ſublimates haſtily raiſed and ſuddenly cooled; we perceive that the parts of theſe ſubſtances cohere very weakly, in the fortuitous contact of them; but that the ſame parts cohere with their greateſt forces, when they are duly poiſed, and rather drawn together by their mutual attractions, than impelled towards each other by any other cauſe: and this indicates their polarity, for the reaſons formerly given.

In talcs, aſbeſti, fluors, cockle and divers ſtony concretes; and even in diamonds, we find that the parts cohere much more forcibly in certain directions than in others: for theſe bodies may be fractured in the direction of their fibres or laminæ, with much leſs force than is required to break them tranſverſely. And the attractions appear to be more forcible in certain faces of the contiguous parts of theſe bodies, than in the others of them; whether we attempt to ſever theſe parts from each other, by mechanical force or by ſolar or culinary fire.

Tranſparent ſtones and glaſſes: the grain and ſtructure of talcs, gypſeous ſpars, aſbeſtus, cockle, bloodſtone and other earthy concretes: the grain and ſtructure of ores, ſemi-metals, allays, and matts: the ſwelling of ſome allays and ſemi-metals, during their ſetting, after being fuſed; and many other ſubjects and phenomena, from which the polarity may be inferred, might be added to thoſe already mentioned; if it were convenient for us todwell longer upon this ſubject.

As water inſinuates itſelf into heaps of powdered earths, and adheres to the ſurfaces of the ſeveral fragments, whoſe aggregation prevents the ſolution of them; ſo portions of air and of other ambient matter, may be ſuppoſed to attach themſelves to the dry ſurfaces of earthy fragments, and to prevent the correſponding ſurfaces from touching, except in a few points, however ſtrongly they be preſſed together: and ſince the number of points, in which large and hard particles of earthy powder can be made to touch each other, is not ſo great as the number of points, whereat ſmaller particles or the atoms can touch one another: both the deficience of contact, and the interpoſition of repellent matter, may, in a ſuperficial view of the recited ſubjects, be aſſumed to explain the phenomena, and to exclude the notion of polarity. There is indeed no reaſon for our rejecting theſe particulars, whilſt we examine the attractions and coheſions of the parts of bodies. The coheſion of poliſhed plates of glaſs or marble, which are ſtrongly preſſed together, or from whoſe contiguous ſurfaces the air is drawn away; and the ſort of coherency which all earthy powders acquire by ſtrong preſſure; and the ſuſpenſion of mercury in the *Torricellian* void, to the height of 60 inches, as *Newton* obſerves; and other appearances, ſhew, that interpoſed matter which is repellent, or which weakly attracts the particles or bodies which it intercedes, and the partial or imperfect contact already mentioned, are to be conſidered as impediments to the coheſion of bodies. But whoever attentively obſerves each of the inſtances related, or alluded to, will find, that after various conceſſions in favour of any particular opinion, the polarity is ſtill deducible from experiment, and neceſſary towards explaining the phenomena.

I know no inſtance of the parts of an earthy powder cohering, ſo forcibly, in conſequence of preſſure, as I have obſerved them to adhere to each other, in the maſs wherewith the miners confine the charge of gunpowder, with which they intend to blow up a rock. On this occaſion, ſmall fragments of ſtone are thrown in, and ſucceſſively rammed down, by means of an iron rammer driven by repeated blows of a ſledge. The ſtones are beaten to duſt in the operation; and the parts thereof muſt touch, in as many points as they may; by reaſon of the force impreſſed on them and driving them againſt each other. In the fortuitous concourſe of ſuch parts, many of them muſt touch where they attract moſt forcibly: and during the concuſſions, few parts will reſt, until they touch each other in the like manner. Wherefore the ſolid aggregate thus formed, is not an exception to the foregoing notion of polarity, illuſtrated in ſo many ſubjects and different circumſtances.

The polarity of the parts of water, may be inferred from the obſervations made on this matter, and arguments ſimilar to thoſe already ſuggeſted.

The particles or ſmall cryſtals of dry ſnow, or of powdered ice, do not forcibly adhere to bodies, or to each other; even when theſe are preſſed together. But when ice becomes liquid, the parts of the water, like thoſe of melted earths or metals, are poiſed; and as the fire is withdrawn, they form a ſolid maſs, and cohere ſtrongly with the bodies which ſtand in contact with them.

Two plates of ice cohere very weakly, by their moſt even ſurfaces, however they be compreſſed; in compariſon with the force wherewith they cohere, when water, ſprinkled on them, is ſuffered to freeze between them, and to cement them together.

Quieſcent water ſlowly frozen, forms regular cryſtals, whoſe form and direction ſtrongly denote polarity; and many other phenomena of water in compounds, eſpecially in ſaline bodies indicate the ſame.

The parts of air repel each other, as do thoſe of acid, or alkali, or any other known element, except earth and water . the attractions which remain to be conſidered are thoſe of the diſſimilar elements. And concerning theſe attractions, it is ſufficient to remark in a ſummary manner, that wherever attraction is demonſtrable, in the aggregates formed of acid and earth, acid and alkali, or of any two or more homogeneal bodies; there, the polarity of the parts of acid, alkali, phlogiſton and air, may be perceived. Having ſhewn how this may be done, with reſpect to earth and water, the inſtances and proofs of polarity in the other elements now mentioned, will readily occur to the reader; who will on the firſt view of them perceive, that they are ſufficiently numerous to fill volumes; inaſmuch as they comprehend all known compounds, which either exhibit, or may be made to exhibit appearances ſimilar to thoſe already mentioned; and that they ſufficiently indicate polarity in the atoms of the ſeveral elements; excepting Light, and the electric fluid, if it be called an element; to either of which I neither aſcribe nor deny this property, at preſent: although in juſtice to Sir *Iſaac Newton*, I tranſcribe the paſſages which firſt led me to the enquiry concerning the polarity of the parts of matter.

Optics, *Query* 26, p. 333. “ Have not the “ rays of Light ſeveral ſides, endued with “ ſeveral original properties? For if the “ planes of perpendicular refraction of the “ ſecond cryſtal, be at right angles with “ the planes of perpendicular refraction of “ the firſt cryſtal, the rays which are re- “ fracted after the uſual manner in paſſing “ through the firſt cryſtal, will be all of “ them refracted after the unuſual manner “ in paſſing through the ſecond cryſtal; and “ the rays which are refracted after the un- “ uſual manner in paſſing through the firſt “ cryſtal, will be all of them refracted after “ the uſual manner in paſſing through the “ ſecond cryſtal. And therefore there are “ not two ſorts of rays differing in their na- “ ture from one another, one of which is “ conſtantly and in all poſitions refracted “ after the uſual manner, and the other con- “ ſtantly and in all poſitions after the un- “ uſual manner. The difference between “ the two ſorts of rays in the experiment

“ mention’d in the 25th queſtion, was only
“ in the poſitions of the ſides of the rays to
“ the planes of perpendicular refraction.
“ For one and the ſame ray is here refracted
“ ſometimes after the uſual, and
“ ſometimes after the unuſual manner, according
“ to the poſition which its ſides
“ have to the cryſtals. If the ſides of the
“ ray are poſited the ſame way to both cryſtals,
“ it is refracted after the ſame manner
“ in them both : But if that ſide of the ray
“ which looks towards the coaſt of the unuſual
“ refraction of the firſt cryſtal, be 90
“ degrees from that ſide of the ſame ray
“ which looks towards the coaſt of the unuſual
“ refraction of the ſecond cryſtal,
“ (which may be effected by varying the
“ poſition of the ſecond cryſtal to the firſt,
“ and by conſequence to the rays of Light)
“ the ray ſhall be refracted after ſeveral manners
“ in the ſeveral cryſtals. There is nothing
“ more required to determine whether
“ the rays of Light which fall upon the
“ ſecond cryſtal, ſhall be refracted after the
“ uſual or after the unuſual manner, but to
“ turn about this cryſtal, ſo that the coaſt

“ of this cryſtal's unuſual refraction may be
“ on this or on that ſide of the ray. And
“ therefore every ray may be conſider'd as
“ having four ſides or quarters, two of which
“ oppoſite to one another incline the ray to
“ be refracted after the unuſual manner, as
“ often as either of them are turn'd towards
“ the coaſt of unuſual refraction; and the
“ other two, whenever either of them are
“ turn'd towards the coaſt of unuſual re-
“ refraction, do not incline it to be otherwiſe
“ refracted than after the uſual manner.
“ The two firſt may therefore be called the
“ the ſides of unuſual refraction. And ſince
“ theſe diſpoſitions were in the rays before
“ their incidence on the ſecond, third and
“ fourth ſurfaces of the two cryſtals, and
“ ſuffered no alteration (ſo far as appears)
“ by the refraction of the rays in their paſ-
“ ſage through thoſe ſurfaces, and the rays
“ were refracted by the ſame laws in all the
“ four ſurfaces; it appears that thoſe diſ-
“ poſitions were in the rays originally, and
“ ſuffer'd no alteration by the firſt refraction,
“ and that by means of thoſe diſpoſitions the
“ the rays were refracted at their incidence

" on the firſt ſurface of the firſt cryſtal,
" ſome of them after the uſual, and ſome of
" them after the unuſual manner, accord-
" ingly as their ſides of unuſual refraction
" were then turn'd towards the coaſt of the
" unuſual refraction of that cryſtal, or ſide-
" ways from it.

" Every ray of Light has therefore two
" oppoſite ſides, originally endued with a
" property on which the unuſual refraction
" depends, and the other two oppoſite ſides
" not endued with that property. And it
" remains to be enquired, whether there are
" not more properties of Light by which
" the ſides of the rays differ, and are diſ-
" tinguiſh'd from one another.

" In explaining the difference of the ſides
" of the rays above mention'd, I have ſup-
" poſed that the rays fall perpendicularly on
" the firſt cryſtal. But if they fall ob-
" liquely on it, the ſucceſs is the ſame.
" Thoſe rays which are refracted after the
" uſual manner in the firſt cryſtal, will be
" refracted after the unuſual manner in the
" ſecond cryſtal, ſuppoſing the planes of

" perpendicular refraction to be at right
" angles with one another, as above: and
" on the contrary.

" If the planes of the perpendicular re-
" fraction of the two cryſtals be neither pa-
" rallel nor perpendicular to one another,
" but contain an acute angle: The two beams
" of Light which emerge out of the firſt
" cryſtal, will be each of them divided into
" two more at their incidence on the ſecond
" cryſtal. For in this caſe the rays in each
" of the two beams will ſome of them have
" their ſides of unuſual refraction, and ſome
" of them their other ſides turn'd towards
" the coaſt of the unuſual refraction of the
" ſecond cryſtal."

Query 29, p. 347;—" And laſtly the un-
" uſual refraction of iſland cryſtal looks very
" much as if it were performed by ſome
" kind of attractive virtue lodged in certain
" certain ſides both of the rays, and of the
" particles of the cryſtal. For were it not
" for ſome kind of diſpoſition or virtue
" lodged in ſome ſides of the particles of the
" cryſtals and not in their other ſides, and
" which

" which inclines and bends the rays towards " the coaſt of unuſual refraction, the rays " which fall perpendicularly on the cryſtal, " would not be refracted towards that coaſt " rather than towards any other coaſt, both " at their incidence and at their emergence, " ſo as to emerge perpendicularly by a contrary ſituation of the coaſt of unuſual re" fraction at the ſecond ſurface; the cryſtal " acting upon the rays after they have paſſed " through it, and are emerging into the " air; or, if you pleaſe into a *vacuum*. And " ſince the cryſtal by this diſpoſition or " virtue does not act upon the rays, unleſs " when one of their ſides of unuſual re" fraction looks towards that coaſt, this ar" gues a virtue or diſpoſition in thoſe ſides " of the rays, which anſwers to and ſym" pathizes with that virtue or diſpoſition " of the cryſtal, as the poles of two magnets " anſwer to one another. And as magnetiſm " may be intended and remitted, and is " found only in the magnet and in iron: ſo " this virtue of refracting the perpendicular " rays is greater in iſland cryſtal, leſs in " cryſtal of the rock, and is not yet found

" in other bodies. I do not ſay that this " virtue is magnetical: it ſeems to be of " another kind. I only ſay, that whatever " it be, 'tis difficult to conceive how the " rays of Light, unleſs they be bodies, can " have a permanent virtue in two of their " ſides which is not in their other ſides, and " this without any regard to their poſition " to the ſpace or medium through which " they paſs."

Quere 31, p. 363.—" When any ſaline " liquor is evaporated to a cuticle and let " cool, the ſalt concretes in regular figures; " which argues, that the particles of the " ſalt before they concreted, floated in the " liquor at equal diſtances in rank and file, " and by conſequence that they acted upon " one another by ſome power which at " equal diſtances is equal, at unequal diſtances unequal. For by ſuch a power they " will range themſelves uniformly, and without it they will float irregularly, and come " together as irregularly. And ſince the particles of iſland cryſtal act all the ſame way " upon the rays of Light for cauſing the un-

" uſual refraction, may it not be ſuppoſed
" that in the formation of this cryſtal, the
" particles not only ranged themſelves in
" rank and file for concreting in regular
" figures, but alſo by ſome kind of polar
" virtue turned their homogeneal ſides the
" ſame way."

If the polarity of matter be admitted, the following queſtions, which expreſs certain objections to our notions of attraction, may be eaſily anſwered.

Why is the force, wherewith a body gravitates to the earth, not ſenſibly leſs, at the diſtance of a few yards from the ſurface of the earth, than it is when it touches the earth: provided the body be hard, and the earth be hard, at the ſurfaces wherein they touch?

Why do maſſes of matter gravitate, at equal diſtances from the earth, with forces equal, in our perception of them; whatever be the faces of them which they preſent to the earth?

Why do hard bodies, whoſe attraction to each other is ſcarcely ſenſible, at the ſmalleſt perceptible diſtances of them, nevertheleſs cohere with conſiderable force, when they are preſſed together ſtrongly, and made to touch each other by their plane ſurfaces? Why do ſoft bodies readily cohere, when they are ſlightly preſſed together? And why do the parts of ſoft bodies or of fluids which harden whilſt fire or menſtrua are withdrawn from them, cohere with the ſtrongeſt attractive forces?

What is the cauſe of the regular ſtructure and grain of divers bodies; and of cryſtalizations, and cryſtaline effloreſcences; and why do all theſe vary with the kinds of matter, and with the proportions wherein theſe kinds of matter are united, in divers compound bodies?

Why do many ſaline liquors, which depoſit no cryſtals whilſt they are quieſcent, ſuddenly cryſtalize through the whole maſs, or depoſit cryſtals, when they are gently moved?

Why do biſmuth and certain allays, and ice formed of water diveſted of fixable air and atmoſpheric air, occupy more room in their ſolid ſtate, than when they are fuſed by fire?

If philoſophers had not indulged themſelves too freely, in aſſuming ethers or material agents; and if they had not ſpent ſo much of their time, in attempting to explain how theſe agents may cauſe the magnetic attraction; they might perhaps before this time have diſcovered, what are the kinds of matter neceſſary to the formation of magnets; what are the laws which govern the attractions of theſe different kinds of matter, which combine electively, cohere, and gravitate indiſputably; and finally by what diſpoſition of the ultimate parts of magnetic bodies, their attraction is enhanced, remitted, directed, or diverted,

It is much to be regretted that no one has made experiments with theſe views; and that for want of ſuch experiments we cannot give a ſatisfactory explanation of the phenomena of magnetiſm, by ſhewing how they may be deduced from ſimple powers of attraction and the law of polarity. But it is not thence to be preſumed, that magnetiſm is an objection to the foregoing notions of attraction: for theſe are not repugnant, but are rather conformable, to each other. The ſeveral inſtances of this conformity may occur to my reader, whilſt he meditates on the following conciſe hints.

The native magnet is an ore of iron, and the parts of this ore, whereon the magnetiſm depends, are the martial earth and phlogiſton; for the iron of this ore obeys the magnet, and may form a magnet; and the iron meliorated, or charged with more phlogiſton, becomes ſteel, and forms the beſt magnets. It is probable that martial earth is a compound conſiſting of earth and ſome other matter not yet aſcertained; and that other matter, beſides earth and phlogiſton, is neceſſary to the formation of magnets or ſteel: but to avoid hypotheſis, I ſhall only conſider the kinds of matter which are well known to be concerned in magnetiſm.

The martial earth, however aggregated, is not truly magnetic; neither is it magnetic in any known combination, except with phlogiſton. The phlogiſton likewiſe, in any combination, except with this earth, doth not form a magnetic body.

Towards magnetiſm it is neceſſary, not only that the phlogiſton and earth be combined and made to co-operate, but that the parts of theſe be arranged in certain order relatively to each other; in which condition of the parts, all ſimple attractive powers operate with their greateſt force, in the contact, or in any diſtances of them. This arrangement, in ſteel, commences in fuſion, is meliorated by well directed motions by percuſſion, and is perfected, near the ſurface eſpecially, by friction repeated in one direction, or by the long continued action of contiguous magnets, during various temperatures of the atmoſphere.

Thus, two or many different ſorts of matter, and a particular arrangement of theſe, are neceſſary to magnetiſm: and ſince our ſimple attractive powers never ceaſe to act, in time, or ſpace, or in combined bodies; they muſt certainly contribute to magnetiſm: and ſince two or more of theſe co-operate, with the utmoſt force of polarity, in magnets, no other power ſeems neceſſary towards magnetic attraction,

If philoſophers will bend their thoughts to the foregoing notions; and will eſtimate the forces of the ſimple attractions, by affixing an arbitrary number to any mean force, and ſmaller or greater numbers to the weaker or ſtronger forces, in juſt gradation: and if they will aſcertain the ratio of each ſimple attractive force, at ſeveral diſtances of the attracting bodies; which ratio I have not attempted to expreſs, becauſe I apprehend that it is not the ſame in all the ſimple attractions; and if they will attend to the compoſition of theſe attractive powers, and to the repulſive powers, of which I have given ſome rude ſketches: I flatter myſelf that they will deduce and explain, from the foregoing principles, the polarity of magnets relatively to each other and to the earth;

and the variations and dippings of magnetic needles; and the different ratios of the forces and diſtances, which diſtinguiſh magnetiſm and gravitation from each other, and from the elective attractions; together with the phenomena of magnetic repulſion, and the others which I have not expreſsly noticed. For my intention, in this introductory diſcourſe, is rather to remove prejudices, and ſhew the grounds on which I ſhall hereafter reaſon from analogy, than to diſcuſs the numerous ſubjects which I have mentioned.

SECT. XII.

Of Saturation.

THE effects of our ſimple powers of attraction and repulſion, and the phenomena which may be explained according to our notions of theſe powers, are much more numerous, than we have hitherto ſuggeſted; and many of them ought to have been noticed, before this time, if my deſign had been to offer every evidence and argument by which theſe notions may be proved. For no other notions, hitherto propoſed, enable us clearly to conceive the reaſon why many bodies are decompoſed, and why a portion of the matter thereof is expelled, when we mix them with other bodies: why, for inſtance, the nitrous acid is expelled from nitre, or the marine acid from ſea ſalt, by mixing theſe ſalts with vitriolic acid: why phlogiſton is expelled from metals, when we immerſe them in acids: why volatile alkali is expelled from ſal ammoniac, when we mix it with cauſtic alkaline ſolutions. Neither do any other notions guide us to the true cauſes, whereby volatile bodies become fixed; ſapid bodies, inſipid; cauſtic bodies, mild; and ſoluble bodies, inſoluble; or to the cauſes whereby divers other relations, conditions, and qualities are induced, ſuppreſſed, or changed, in bodies.

Of theſe effects and appearances, there is only one, which we may not paſs over in ſilence: and this one is what the chemiſts expreſs by the word *Saturation.*

When an earth is preſented to an acid, a certain quantity of the earth is diſſolved, and is combined with the acid; and if it be aſked, Why the acid does not diſſolve more? We are told, the acid is ſaturated. When an earth combines with a certain quantity of phlogiſton, and will not combine with more; when alkali combines with a certain quantity of the elaſtic fluid, called fixable air, and will not unite with more; when the like happens on mixing acids and alkalies, oils and ſpirits, ether and water, and on mixing various other bodies; the chemiſts, inſtead of ſhewing the reaſon why one of theſe can combine with another, to a certain quantity and no more, content themſelves with ſaying, "*The* "*body is ſaturated*;" or, "*The tendency of theſe* "*bodies to unite, is ſatisfied.*"

This important ſubject did not eſcape the notice of the ſagacious *Newton*; whoſe notions of it, may be gathered from the paſſage tranſcribed in page 120, of this Introduction, and from the following part of the thirty-firſt Query, in his Optics.— "The attractions of gravity, magnetiſm and "electricity, reach to very ſenſible diſtances, "and ſo have been obſerved by vulgar eyes, "and there may be others which reach to "ſo ſmall diſtances as hitherto eſcape obſer- "vation; and perhaps electrical attraction "may reach to ſuch ſmall diſtances, even "without being excited by friction.

"For when ſalt of tartar runs *per deliquium*, "is not this done by an attraction between "the particles of the ſalt of tartar, and "the particles of the water which float in "the air in the form of vapours? And why

“ does not common ſalt, or ſalt-petre, or vi-
“ triol, run *per deliquium*, but for want of
“ ſuch an attraction? Or why does not ſalt
“ of tartar draw more water out of the air
“ than in a certain proportion to its quantity,
“ but for want of an attractive force after it
“ is ſatiated with water? And whence is it
“ but from this attractive power that water
“ which alone diſtils with a gentle lukewarm
“ heat, will not diſtil from ſalt of tartar with-
“ out a great heat? And is it not from the
“ like attractive power between the particles
“ of oil of vitriol and the particles of water,
“ that oil of vitriol draws to it a good quan-
“ tity of water out of the air, and after it is
“ ſatiated draws no more, and in diſtillation
“ lets go the water very difficultly?”

Hence we learn that our illuſtrious author entertained an opinion, that particles of matter which attract at ſmall diſtances between them, repel at greater diſtances; and that a particle which coheres with a certain number of contiguous particles, cannot attract any particles beyond theſe, by reaſon of their diſtance; and conſequently that a body can combine with only a determinate quantity of another body; which laſt phenomenon is called ſaturation.

But there is no reaſon for ſuppoſing that particles which mutually attract, when they touch, do repel at any diſtance of them. On the contrary, it appears, that particles attract each other, at diſtances much greater than the intervals which can be imagined to intercede them, in the denſe fluids which are ſaturable: and on divers other conſiderations, this explanation of the cauſe of ſaturation, is unſatisfactory; and to diſcover the true cauſe of it, we muſt have recourſe to our ſimple powers of attraction and repulſion. If theſe powers are ſufficient for the phenomena of ſaturation; and if, in conformity with their ſeveral forces, we can moreover ſhew, why certain fluids, which attract and ſaturate each other, do not form a fluid, denſe like water, or an aggregate, ſolid like ice or ſalt; theſe powers are to be admitted as the cauſes of ſaturations: and other cauſes, being unneceſſary, are to be rejected. To this end, I ſhall ſhew, in a few inſtances, how the moſt intricate phenomena are deducible from the foregoing principles.

The force, wherewith water attracts earth, being much weaker that that whereby earthy atoms are united and aggregated, is ſufficient to prevent the combination of any conſiderable quantity of earthy matter with water: for when the ſeveral atoms of an earthy body, are placed near each other in water; theſe atoms, being urged to approach, with greater force than that wherewith they are attached to contiguous atoms of water, muſt unite, until they form molecules whoſe gravitation is ſufficient to overcome the attraction of the water; and they muſt then precipitate, or adhere to ſome neighbouring ſolid body. For the like reaſon, an homogeneal maſs of earth, or a powder conſiſting of molecules of earth, ought not to diſſolve in water, or to combine with it, in any conſiderable quantity. And this inference from the ſimple attractions of earth and water, agrees with experience; for nature, or art, hath not hitherto preſented us with ſuch a compound.

We have inſtances of ſmall portions of earthy matter diſſolved in water; and of water, ſo impregnated, being incapable to ſuſpend any additional quantities of the like earthy matter. But concerning theſe we are to obſerve; that as the forces of all attractions decreaſe, whilſt the diſtances between the bodies encreaſe; atoms of earth, widely diffuſed in water, will remain ſuſpended therein and united with watry atoms: becauſe the force, wherewith atoms of earth far diſtant from each other, are drawn together, can be reſiſted by the force wherewith they are attached to the watry atoms which they touch, and is reſiſted by the tenacity and gravity of water; ſince the earthy atoms cannot approach each other, without diſplacing thoſe of water. By reaſon of theſe reſiſtances, water may hold a ſmall quantity of earthy matter permanently ſuſpended, ſo long as the water is not violently agitated. But the water cannot be ſaid to be ſaturated; becauſe a *tertium quid* is not formed; and the earth is not ſaturated, becauſe the ſolution will blend or unite with any quantity of water. Wherefore, if it be thought, that the water of certain rivers, and of petrefying lakes, or that lime water, and certain chemical operations, afford us proofs of the ſolution of a ſmall quantity of pure earthy matter in large quantities of water; theſe are not incompatible with our principles: neither is it repugnant to them, that water ſo impregnated, and ſtreaming along earthy bodies, ſhould depoſit thereon ſucceſſively a portion of the earth which it carried; and that the atoms of earth, ſo drawn from water, ſhould form a regular and ſolid aggregate, in the lapſe of time; nor is it inconſiſtent with them, that water, impelled againſt, or trickling, or ſtreaming in contact with ſolid earthy aggregates, in diſtillations, drippings, and currents, ſhould abrade and ſuſpend a portion of the earthy matter of ſuch aggregates.

But when we conſider that a great quantity of acid and alkaline matter, is every moment extricated from bodies in divers operations of nature; and that the parts of ſuch matter, receding from each other, circulate to bodies which attract them: and when we recollect that acid and alkaline fluids ſtrongly attract water and earth ; we find, it is highly improbable, that any conſiderable portions of pure earth and pure water, can ever meet ; and we may reaſonably infer, that the ſolutions, which we ſee, of earth in water, are not effected and continued by the ſole power of attraction ſubſiſting between earth and water ; but by other powers of attraction co-operating with them. For if the power of the attraction of acid or alkali to earth, act in conjunction with that of earth to water ; theſe combined forces ought, agreeable to the premiſes, to effect the ſolution of much greater quantities of earth in water, than can be done by water alone ; and we accordingly find, that by the mediation of acid or alkali, earth may be diſſolved permanently in a quantity of water, not exceeding the earth in weight ; as it is, in earthy ſalts, and in the gelatinous maſſes, or the viſcid ſolutions, of ſeveral earthy bodies fuſed with a triple quantity of fixed alkali. From theſe and other inſtances, compared with waters ſlightly impregnated with earthy matter, we learn that nothing like a combination, or a *ter-*

tium quid of the chemiſts, is formed by earth and water unaſſiſted by any other matter; and that they cannot ſaturate each other.

If the forces wherewith the parts of earth attract each other, were leſs than thoſe, with which theſe parts attract the parts of water; earth and water ought, according to our principles, to unite in all proportions of them; in the ſame manner as the attractive parts of earth unite with each other, and as the attractive parts of water unite with each other, whatever be the quantity of them. And towards our ſucceeding, in the inveſtigation of the true cauſe of ſaturation, it is highly neceſſary to obſerve, that bodies, whoſe homogeneal parts as well as their heterogeneal parts attract each other, ought not, according to our principles, to ſaturate each other; and that ſuch bodies do not ſaturate each other.

As the next ſtep towards deducing the phenomena of ſaturation from the primary powers of attraction and repulſion, and at the ſame time recommending our notions of theſe to the conſideration of philoſophers; we proceed to the combinations of bodies whoſe parts attract reciprocally, with thoſe which have the repellent property.

Alkaline atoms repel each other; and when they ſtand diſtant from each other, cannot be approximated, without ſome power to counteract that of their repulſion. When they are drawn together by the attraction of water; as when we receive the elaſtic alkaline fluid in water, and thus compoſe the cauſtic volatile alkali, the parts of water muſt be arranged alternately with parts of alkali; becauſe each atom of water which attracts alkaline atoms, muſt be drawn into the line between them, whilſt it draws them towards each other, contrary to their repulſive force.

Of a determinate number of watery atoms, the ſum of the attractive forces muſt be nearly equal to the repulſive forces of a certain number of alkaline atoms; and according to our principles, ſo much water, ought to condenſe or hold in combination, ſo much alkali, and no more. For if any additional portions of alkali be preſented, they are indeed attracted by the water, but they are repelled by all the alkali which the water can hold ; and as the parts of theſe portions repel each other, they muſt recede from each other, and from the water. And this inference from our principles, agrees with experience.

But if it be true, that water is capable of being ſaturated with alkali, by reaſon of the mutual attraction of water and alkali, and of the reciprocal repulſion of alkaline atoms ; and if our principles of attraction and repulſion be juſt, it is to be expected that, although water can be ſaturated by alkali, alkali cannot be ſaturated by water, ſo as to refuſe union with any additional quantities of water. Becauſe the parts of water, which attract each other as well as they attract thoſe of alkali, can have no tendency to recede or ſeperate from the compound of alkali and water. And we are not deceived in this expectation flowing from our premiſes ; for any quantity of water, will blend and unite with the ſmalleſt portion of alkali ; although any quantity of alkali will not abide with a ſmall portion of water.

The chemiſts labour in vain, who attempt to draw the cauſtic vol. alkali the ſtronger, as they uſe the leſs water in the proceſs. As fire counteracts attractive forces, hot water cannot hold ſo much of the alkaline elaſtic fluid, as cold water retains. The water which is kept cool whilſt it receives the alkaline fluid, holds a much greater charge thereof, than we find in water diſtilled from the materials which yield the alkaline matter. And we found the charge of alkali which water can imbibe, to be the greateſt when we counteracted the repulſion of the alkaline atoms, by the greateſt compreſſing forces which our veſſels could endure. Whence it further appears that the repulſion of the parts of alkali, is the cauſe which limits the quantity of alkali which water can hold, and is conſequently the cauſe of the ſaturation now under conſideration.

In the ſame manner we deduce from the ſimple powers of attraction, aſſumed as principles, the phenomena of ſaturation, between water and acid, water and air, earth and acid, earth and phlogiſton, or any two elements, one of which conſiſts of atoms which attract mutually, and the other of parts which repel reciprocally: and we are enabled to anſwer the following queſtions.

Why does an earthy body concentrate, and combine with, and form a *tertium quid* with, a certain quantity of acid? and why is it incapable of concentrating more, or uniting with more? On the other hand, Why may a certain quantity of acid be blended and combined with the greateſt quantity of earth: As we ſee, in earthy and metallic ſalts formed with the purer acids; all which ſalts will blend and form aggregates with any quantity of earthy matter?

Why are earthy bodies capable of concentrating, and combining with, and forming a *tertium quid* with phlogiſton, in certain proportions, but incapable of holding more, or uniting with more than a determinate quantity thereof? And why a ſmall portion of phlogiſton can blend, and unite with any greater quantity of earth; as we experience in metallic calces, and phlogiſticated glaſſes?

Why only a certain quantity of air can unite or adhere to an earthy body? and why the compounds which are elaſtic like air; that for inſtance which is called fixable air; and that which received in water makes the mantling nitrous acid; and that which with water makes the the vol. vitriolic acid; are capable of being condenſed and combined with water or earthy bodies, or fixed compounds, to a certain quantity, and not in any greater quantity?

Why water imbibes a certain quantity of air and no more; and why any quantity of water may be united with a ſmall quantity of air: but any quantity of air may not be united with a ſmall quantity of water?

Theſe queſtions, and their anſwers, comprehend numerous inſtances in which we find that a body whoſe parts repel cannot be ſaturated by a body whoſe parts attract each other; but that an homogeneal body or a componud compound whoſe parts attract each other, ſo as to be held in contact, can be ſaturated by, or can unite with only a determinate quantity of, a repellent element, or elaſtic compound: and in all theſe circumſtances, and combinations, the effects are thoſe preciſely which are deducible from our principles, to which nothing appears contradictory. And as attractive powers manifeſtly cauſe combinations in any proportions of the bodies, whoſe parts all attract each other; ſo the exceſs of repulſive, above the attractive forces, is truly the cauſe of ſaturation.

Theſe obſervations being premiſed, we can the more clearly deduce the other more ſtriking ſaturations from our primary powers.

When a portion of acid matter tolerably pure, is detached from any compound which contained it in a ſtate of ſaturation, or from the common acids of the chemiſts; and when the elaſtic inviſible fluid, conſiſting chiefly of repellent acid atoms, is introduced into the *Torricellian* void, in ſuch quantity as is neceſſary

ſary to ſink the mercury to the level of that which is in the baſon ; if the elaſtic alkaline inviſible fluid, obtained tolerably pure from neutral ſalts or the cauſtic vol. alkali of the chemiſts, be thrown in, to blend with the acid fluid ; and if the relative quantities of theſe be properly adjuſted, the two fluids combine and form a neutral ſalt : and as this ſalt occupies but a very ſmall part of the ſpace from which the mercury was excluded by the fluids, the mercury riſes more or leſs nearly to its former height, as the fluids employed were more or leſs homogeneal, or accurately proportioned to each other. If in another veſſel the like experiment be made, ſo that the mercury which was depreſſed by the introduction of one elaſtic fluid, ſhall riſe, in proportion as we introduce the other elaſtic fluid ; and if the fluids be mixed in the quantity neceſſary for their reciprocal ſaturation, ſo that the mercury in both veſſels ſhall ſtand at the ſame height, and nearly as high as it is wont to do in the barometer ; and if into one of theſe veſſels we introduce ſucceſſive portions of alkaline fluid, the mercury

cury will ſink gradually; and when we throw, into the other veſſel, an acid elaſtic fluid by degrees, the mercury will here alſo ſink by degrees, as the acid fluid is introduced.

From theſe and divers other experiments, we learn that acid and alkaline matter can ſaturate each other and combine, only in determinate quantities of theſe relatively to each other. And ſince the power of attraction can only operate towards approximating and combining the acid and alkaline atoms, it appears that the power wherewith the homogeneal parts repel each other, is the cauſe of the ſaturation. Many evidences to this effect might be produced, if we had time to enumerate the inſtances ſhewing that divers repellent matters ſaturate each the other; whilſt any one of theſe ſaturates attractive matter; ſuch as earth or water, but is not ſaturable thereby.

In order to illuſtrate this ſubject; let the circles *a a a*, &c. and the circles *b b b*, &c. Fig. I. repreſent ſeveral atoms of acid and of alkali. And ſince the acid atoms *a a a*, &c. repel each other, and attract the alkaline atoms *b b b*, &c. and ſince the alkaline atoms *b b b*, &c. repel each other and attract the acid atoms *a a a*, &c. The arrangement of ſuch atoms, in any plane bounding or paſſing thro' the ſolid compound of acid and alkali, muſt, by reaſon of theſe forces, be accurately or nearly that which is repreſented in the figure; wherein atoms of acid are ſhewn to intercede and touch atoms of alkali, which ſtand diſtant from each other; and atoms of alkali appear interpoſed between, and in contact with acid atoms, which are diſtant from each other.

Now, in this compound, if the forces, wherewith the acid atoms *a a a*, &c. attract the alkaline atoms *b b b*, &c. be nearly equal to the forces, wherewith the homogeneal atoms *a a a*, and the homogeneal atoms *b b b*, repel each other: it follows from our principles, that no additional number of acid or alkaline atoms can adhere to, or combine with the compound thus formed: for whether an alkaline atom *c* be applied, ſo as to touch the like alkaline atom *b*; or whether an alkaline atom *d* be applied, ſo as to touch an acid atom *a*, and an alkaline atom *b*; or whether the alkaline atom *e* be applied ſo as to touch only an acid atom *a*; the ſum of the forces, whereby the alkaline atom ſo applied is repelled by the contiguous, and by all the alkaline atoms *b b b*, &c. being equal, by the hypotheſis, to the ſum of the forces wherewith it is attracted by the contiguous, and by all the acid atoms *a a a*, &c. There is no unreſtrained agent to cauſe the alkaline atom *c*, or *d*, or *e*, to adhere to the compound in any plane or ſection thereof repreſented by this figure. And the ſame may be ſaid of any number of alkaline atoms, and alſo of any number of acid atoms preſented to ſuch a compound.

But although the forces wherewith the acid atoms *a a*, &c. attract the alkaline atoms *b b b*, &c. were greater than the forces wherewith the homogeneal atoms repel each other; and although theſe attractive forces be really greater in the ſum and in detail, than the repulſive forces, becauſe the compound could not otherwiſe be a firm aggregate ſuch as we find it, and could not ſo forcibly reſiſt fracture as we know it does; the fluid conſiſting of the atoms *a a a*, &c. and that compoſed of atoms *b b b*, &c. will nevertheleſs ſaturate each other; and the aggregate *a b a b a b*, &c. formed of ſuch fluids, will be found incapable of combining with any additional quantity of either kind of matter. For, when the attractive forces, of equal numbers of acid and alkaline atoms, are prevalent over the repulſive forces of the homogeneal atoms, the prevalent attractive power, will enable the compound to draw and hold a certain quantity of acid, or of alkali, beyond the equal quantities of theſe; but this will be a limited quantity, becauſe the attractive force which was prevalent, muſt be equalled and counteracted by the repulſive forces of a certain number of the ſuperadded repellent atoms: and then the aggregate thus formed will not hold in combination any more of the predominant matter, for the reaſons already aſſigned.

Whoever attentively conſiders theſe things, may readily anſwer the following queſtions.

Why do many ſalts cryſtalize nearly neutral, in a liquor containing a ſuperabundant quantity of acid or of alkali?

Why much water doth combine in the cryſtals of moſt neutral ſalts? and why this *water of cryſtalization* ſeparates from the ſuperfluous acid or alkali, and introduces little or none of either into the cryſtals?

Why is the ſmall portion, of either acid or alkali, which adheres to ſuch cryſtals, by reaſon of the water of the mother liquor, wherewith they are wetted, eaſily waſhed off, ſo as to leave the cryſtals perfect and neutral, or ſo nearly ſo, that chemiſts have generally conſidered them as neutral?

When any two different elaſtic fluids form a ſolid or palpable aggregate; as when the elaſtic fluid called fixable air and the elaſtic alkaline fluid ſaturate and condenſe each other, and form the ſolid ſalt called *ſal volatile*

tile ſalis ammoniaci: and when two or more elaſtic fluids are combined with other matter; as phlogiſton, acid, and alkali are, with water, in *Boyle*'s ſmoaking liquor; or as phlogiſton, acid, and alkali are, with earth, in *hepar ſulphuris*: or as acid and atmoſpheric air are, with water, in the liquor called ſpirit of nitre; or as phlogiſton, acid, and air are with water, in *ſpiritus nitri dulcis*: and when any compounded bodies ſaturate each other, and are found incapable of uniting except in certain proportions: and in general when ſubtile fluids form ſolid bodies, or adhere to ſolid bodies; and when they refuſe to combine with each other or with bodies, or to adhere to bodies, in any greater than a determinate proportion: theſe phenomena are eaſily explained according to the foregoing principles; and afford additional proofs of the truth of this theory of ſaturation.

What we have ſaid of ſaturation will be found uſeful in our future enquiries concerning Light; but it more immediately aſſiſts us in explaining other phenomena of combinanation and ſaturation, which I am now to mention; and which bear a cloſer analogy to thoſe of Light and Fire.

If the Fire of combuſtions, decompoſitions, colliſions, and frictions in which heat is felt, be a compound fluid conſiſting of two different kinds of matter united and forming a *tertium quid*: Or if the elaſtic fluid, which with water forms the nitrous acid, be a compound conſiſting chiefly of air and acid matter: Or if air contracted, and rendered unfit for reſpiration, and incapable of aſſiſting in the combuſtion of bodies, when it is impregnated with phlogiſtic matter, be a compound fluid: Or if the elaſtic inflammable fluid, called inflammable air, be a compound fluid: Or if there are other inſtances of fluids, which are compounds, and whoſe properties are different from thoſe of the elements of which they are reſpectively compoſed; and which are nevertheleſs permanently elaſtic: It may be truly ſaid that divers elaſtic fluids, which attract each other, may be combined, and may form a compound, whoſe properties are different from those of the component fluids; even whilſt the compound preſerves the condition of an inviſible elaſtic fluid, inſtead of forming an aggregate, ſuch as is produced by the union of the elaſtic fluids formerly mentioned in this ſection. But to avoid the ſubjects concerning which philoſophers entertain various diſcordant opinions, I for the preſent propoſe only the elaſtic inflammable fluid, called inflammable air, as an inſtance of this kind of combination. For ſince this inflammable fluid can be formed whenever we pleaſe; ſince nothing is neceſſary to the formation of it, except acid and phlogiſtion, although it be occaſionally blended with other matter; ſince it is always formed, when homogeneal acid and phlogiſton are detached together from bodies, or preſented to each other; ſince we have lately diſcovered the method of decompoſing it; ſince the combuſtibility, and the ſyntheſis, and analyſis of this fluid, all clearly ſhew that it is a compound conſiſting of acid and phlogiſton; and ſince it is manifeſtly elaſtic, and differs in many properties from the acid and from the phlogiſton whereof it is formed; this inflammable fluid is an unexceptionable inſtance, of two different elaſtic fluids remaining elaſtic, even after they have combined with each other, and formed a *tertium quid*.

To explain theſe phenomena no new properties of matter are to be aſſumed. For as the attractive forces are ſaid to be prevalent over the repulſive forces, when acid and alkaline elaſtick fluids form a ſolid ſalt; ſo it is clearly deducible from the elaſticity of certain compound fluids, that the homogeneal atoms thereof repel each other more forcibly than the heterogeneal atoms atract each other, at any given diſtances between them. And this prevalence of the repulſive forces, is all that is neceſſary toward our underſtanding the reaſon why ſome fluids remain elaſtic, after they have ſaturated each other and formed a *tertium quid*.

Let the circles *a a a*, &c. Fig. 2, repreſent the acid atoms, in any plane bounding or paſſing through the acid elaſtic fluid retained in a veſſel, and held equally diſtant from each other by repulſive powers decreaſing in any reciprocal ratio of the diſtances between them: And let an equal number of phlogiſtic atoms *b b b*, &c. which alſo repel each other in any reciprocal ratio of the diſtances of them, not widely different from the foregoing ratio; be preſented to the acid atoms *a a a*, &c. And let the acid and phlogiſtic atoms attract each other, with forces, which are in any aſſumed reciprocal ratio of the diſtances between them: But let theſe forces be leſs than than thoſe, wherewith acid atoms, or phlogiſtic atoms repel each other at the ſame diſtances between them. Now, becauſe the phlogiſtic atoms *b b b*, &c. tend to ſtand equally diſtant from each other, and the acid atoms *a a a*, &c. tend to ſtand equidiſtant from each other, by reaſon of the premiſed repulſions; whilſt the acid atoms *a a a*, &c. tend to unite with the phlogiſtic atoms *b b b*, &c. by reaſon of the premiſed attractions; the phlogiſtic atoms *b b b*, &c. thrown amongſt the acid atoms *a a a*, &c. muſt arrange themſelves ſo that an atom of the one fluid ſhall intercede two atoms of the other in every ſeries of atoms lying in the ſame right line; and if they do not arrange themſelves preciſely in the order expreſſed in Fig. 3. wherein *a a a*, &c. repreſent acid atoms and *b b b*, &c. phlogiſtic atoms; they muſt arrange themſelves in another order, wherein the repellent atoms may be equidiſtant, and each phlogiſtic atom ſhall touch an acid atom, and the atoms of phlogiſton ſhall be arranged alternately with acid atoms in every ſeries of atoms ſtanding in a right line: And as any ſuch order is as ſuitable to our preſent illuſtration, as that is which Fig. 3. exhibits, no other order beſides that in Fig. 3. needs to be repreſented or particularly conſidered. For as it is impoſſible, by reaſon of the tremulous motions of the earth and its atmoſphere, and by reaſon of the laws by which bodies communicate motion and perſiſt in their ſtate of motion, that a piece of iron can remain for any ſenſible time in a place between the earth and a ſuſpended magnet, at the diſtances from theſe, at which the magnetic attraction is preciſely equal to the gravity of the iron: And as it is therefore impoſſible that the iron ſhould remain for any ſenſible time ſuſpended between the magnet and the earth; ſo it is impoſſible, in any ſyſtem of phlogiſtic and acid atoms which are moved whilſt they are preſented to each other, or which do acquire ſome motion every moment, that the phlogiſtic atoms *c c c*, &c. Fig. 2. mixed with the acid atoms *a a a*, &c. can remain poiſed at equal diſtances and by equal powers of attraction, between the acid atoms *a a a*, &c. in the manner repreſented in this figure. And whoever conſiders the attractive and repulſive forces of theſe atoms, will eaſily diſcover that the union of one acid with a phlogiſtic atom in a ſyſtem compoſed of any number of theſe, muſt immediately be followed by the like union of the other acid and phlogiſtic atoms of the whole ſyſtem.

I therefore ſay again that whenever two elaſtic fluids whoſe homogeneal parts repel each other, and whoſe heterogeneal parts attract each other according to the foregoing laws, are blended together; the homogeneal atoms *a a a*, &c. Fig. 3. will remain equidiſtant; and the homogeneal atoms *b b b*, will remain equally diſtant from each other; whilſt the heterogeneal atoms *a b*, *a b*, *a b*, &c.

will form the ſolitary molecules *a b*, *a b*, *a b*; And theſe molecules will recede from each other by how much force the repulſive powers exceed the attractive powers; and as the repulſive powers vary with the diſtances, as well as the attractive powers vary with the diſtances, of the atoms, a compound fluid conſiſting of ſuch molecules will be compreſſible, and indefinitely expanſible, by virtue of theſe repulſive powers.

But ſince the attractive forces, counteract the repulſive forces, ſuch a compound fluid will not under any given atmoſpheric preſſure occupy ſo much ſpace, or expand ſo widely, as one of the homogeneal fluids whereof it conſiſts. If the fluids conſiſting of the atoms *a a a*, &c. Fig. 3. ſuſtains the preſſure of the aerial atmoſphere; and if the ſum of the forces, wherewith the atoms repel each other at theſe diſtances between them, be equal to the force whereby they are compreſſed by the atmoſphere, or by any other power; the introduction of another fluid whoſe atoms *b b b*, &c. attract the atoms *a a a*, &c. muſt neceſſarily cauſe a reduction of the volume of the fluid *a b*, *a b*, *a b*, &c. becauſe the forces, wherewith the parts of the two different fluids attract each other, will co-operate with the force of the atmoſpheric preſſure, and render it equivalent to a greater force of atmoſpheric preſſure, towards the condenſation of the firſt fluid *a a a*, &c. And as hetoregeneal atoms or bodies, when combined, form a *tertium quid*, and ſaturate each other; the compound conſiſting of the molecules *ab*, *a b*, *a b*, &c. will be a *tertium quid*; and the elaſtic fluids, whereof this compound is formed, will be ſaturated reciprocally, or may be ſaturated by each other. And the ſame compound elaſtic fluid muſt alſo be inviſible; becauſe neither atoms nor molecules are ſeverally viſible; and becauſe all bodies become inviſible, when their molecules are removed to a ſmall diſtance from each other.

Theſe conſequences will alſo follow; whether the attractive and repulſive forces be reciprocally as the diſtances in a duplicate ratio; or whether they be reciprocally as the ſquares of the diſtances, or reciprocally as the cubes of the diſtances, or in another reciprocal ratio of the diſtances; provided only that the heterogeneous atoms attract each other leſs forcibly than the homogeneal atoms repel each other at any given diſtance between them.

The effects, which we thus deduce from the powers of attraction and repulſion, which indiſputably actuate the parts of compounded elaſtic fluids, and which we do not limit to any controvertible ratio of the diſtances, are preciſely the ſame which occur in nature.

The fluid called inflammable air is experimentally compreſſible; and we cannot affix any limits to its expanſibility. Its properties are different from thoſe of the acid matter or of the phlogiſtic matter whereof it is compoſed; and it refuſes to combine with any additional quantities of acid, or of phlogiſton, however preſented to it. Acid matter may indeed be mixed with it, but no combination of the ſuperabundant acid takes place; becauſe this ſuperfluous acid is readily drawn from the inflammable fluid, and imbibed by water, when the mixture is expoſed to water: but the inflammable fluid is very ſlowly, or not at all imbibed by water, when atmoſpheric air or other matter is prevented from mixing with the inflammable fluid.

We moreover find this elaſtic inflammable fluid to be always inviſible, when no other matter, beſides acid and phlogiſton, is admitted in the compoſition of it.

In the ſame inflammable fluid we may alſo perceive, that the phlogiſtic atoms are approximated, by means of the interpoſed acid atoms; for theſe parts recede from each other, and in receding cauſe terrible exploſions, in the moment when the union of the phlogiſtic atoms with the acid atoms is diſſolved, which happens in the quick combuſtions of this inflammable fluid.

But this is more readily perceived in phlogiſticated air, and other elaſtic fluids. For conformable to our reaſoning *a priori*, atmoſpheric air, impregnated with phlogiſtic matter, whether by calcining metals in it with ſolar heat, or by preſenting phlogiſton to it in any proceſs, or from any phlogiſtic body as well as from the mixture of iron-filings, ſulphur and water; is reduced in volume, even by the phlogiſton which is ſuperadded; and the air ſo phlogiſticated, is found to poſſeſs properties different from the atmoſpheric air; and the phlogiſticated air remains an elaſtic inviſible fluid; and is incapable of reducing the volume of atmoſperic air, or of being reduced in volume thereby: and air, once fully phlogiſticated, is found incapable of being altered in its properties, or of being further reduced in volume, by the acceſs of more phlogiſtic matter, which affects atmoſpheric air in the manner already expreſſed.

Moreover, with the like conformity, the elaſtic fluid, which is detached during the haſty ſolution of metals in the nitrous acid, being mixed with air; we find the mixed fluids to be leſſened in bulk conſiderably, and the mixture nevertheleſs to preſerve the condition of a permanently elaſtic inviſible fluid. For, altho' the fluids, in mixing, be for a moment turbid and perceptible to the eye, by reaſon of their unequal denſities, they become inviſible ſo ſoon as their parts aſſume the arrangement to which their reſpective attractions and repulſions compel them: and the greateſt reduction of the volume of theſe fluids, in mixing them, is effected when they are mixed in determinate proportions: for, a ſuperabundant quantity of either fluid, added to the mixed fluids, will encreaſe the volume of the mixture, in the ſame manner as a portion of air added to a portion of air will encreaſe the volume thereof.

In our preſent conſideration of this ſubject, it is unneceſſary to enquire whether phlogiſton be detached from the nitrous elaſtic fluid when it is mixed with air. But we may remark that the experiment of mixing the nitrous elaſtic fluid with air was firſt made by Doctor *Hales*; but it was reſerved for a more modern experimenter to make the following obſervation on it, in the work, entitled, *Experiments and Obſervations on differents kinds of Air*, vol. I. p. 111. "I hardly know any experiment "that is more adapted to amaze and ſurprize

"than this is, which exhibits a quantity of
"air, which, as it were, devours a quan-
"tity of another kind of air half as large as
"itſelf, and yet is ſo far from gaining any
"addition to its bulk, that it is conſiderably
"diminiſhed by it."

From many other experiments and obſervations, confirming the inferences made from our principles, we learn that the elaſticity of certain compound fluids is cauſed by the exceſs of the repulſive forces of the homogeneal atoms, above the attractive forces of the heterogeneal atoms of them, in the manner already ſet forth; and ſome of theſe obſervations may be made by any perſon who knows, that, when theſe compound fluids are blended with matter which forcibly attracts their molecules, theſe molecules are no longer held diſtant, and do not thereafter form an elaſtic fluid; but do by reaſon of the prevalent attractive forces of the matter wherewith they are mixed, form with it palpable fluids or ſolid aggregates; a few inſtances of which may eaſily be collected from the foregoing pages of this ſection.

After this brief explanation, I preſume that my reader may give ſatisfactory anſwers to the following queſtions.

Why are elaſtic fluids detached from oils, ardent ſpirits, and many other phlogiſtic compounds, when concentrated acids act on them ?

Why do portions of ſolvents, or of bodies diſſolved, or of both the ſolvent and diſſolved bodies, eſcape from the mixtures, and form different elaſtic fluids, in numberleſs proceſſes of nature, and of the chemiſts and artiſts ?

Why doth phlogiſton eſcape from metals and other compounds when acid matter acts on them and combines forcibly with the matter which held the phlogiſton in the compounds ; and why doth a part of the eſcaping phlogiſton carry acid with it, and form, with this acid, inflammable air ; whilſt other portions of the departing phlogiſton, eſcape thro' the veſſels in the form of fire, ?

Why are the acid, alkaline, phlogiſtic and aerial parts of compound bodies, volatilized and expelled by fire, more readily than the earthy parts of theſe bodies ?

Why are all bodies conſiſting of many different kinds of matter, decompoſed by the action of fire.

Why do divers compound bodies, and particularly animal and vegetable ſubſtances, emit permanently elaſtic fluids, when fire only, acts on them in cloſe veſſels ?

Why does the air, which adheres to metallic calces, and forms a part of the ſolid maſs of theſe and other bodies, reſume its elaſticity when they are ignited ?

What is the power by which ſolid bodies are formed of elaſtic fluids; and why do many ſolid ſubſtances compoſed chiefly of phlogiſton, acid, alkali, and air, expand widely, and explode forcibly, when they are ignited ? And why are the expanded fluids poſſeſſed of properties different from thoſe of the acid, or alkali, or air, or other homogeneal matter, of which the exploſive ſubſtances were compoſed ?

Why do bodies which are expoſed to the preſſure of the air, or to any other preſſure, retain much more repellent matter than they can hold when that preſſure is averted? Why, for inſtance, does an elaſtic fluid agitate water and cauſe an ebullition of it, and eſcape from the water which is placed in the receiver of an air-pump, whilſt we exhauſt the air? Why do certain liquors, ſuch as water impregnated with the elaſtic acid fluid which is diſengaged from nitre and arſenic, in the operation for neutral arſenical ſalt, and ſuch as the cauſtic volatile alkali, and ether, mantle and move as if they were boiling, and diſcharge elaſtic fluids in abundance, when the preſſure of the atmoſphere is removed from them?

Why does the elaſticity of the fluid called fixable air, ceaſe when this fluid is imbibed by water, alkali, or lime, and why do theſe imbibe the elaſtic fluid the ſooner, by how much the oftener we preſent, to the fixable air, new ſurfaces of them, at which they have not yet imbibed any of it?

Why do elaſtic fluids, which are capable of condenſing each other, act ſlowly to this effect, when the heavier fluid is thrown under the lighter fluid, ſo as to touch it: and why do they act quickly to the ſame effect, when the lighter fluid is thrown under the heavier fluid, ſo that it may touch it and mount thro' it?

Why may the elaſtic inflammable fluid, diſcharged during the ſolution of iron or zinc in the vitriolic acid, be expoſed to alkaline *lixivia*; and why may it be puſhed through them, in ſlender ſtreams; without ſuffering any conſiderable diminution of its bulk: and why does the elaſticity of the ſame inflammable fluid, ceaſe immediately, when a certain quantity, of the elaſtic alkaline fluid is admitted to it? And when this experiment is made in the *Torricellian* void, and when only the neceſſary quantity of the alkaline fluid is introduced to the inflammable fluid;

why doth the mercury riſe ſuddenly, as it would if the matter of theſe fluids were annihilated? But when more than this quantity of the alkaline fluid is thrown in to the inflammable fluid, why doth the mercury riſe in the tube, to a height, which is reciprocally as the exceſs of the alkaline fluid?

Many other queſtions, concerning phenomena which have not been explained, but which may readily be explained according to the foregoing principles, might be ſubjoined. But theſe now propoſed will anſwer my preſent purpoſe: which is to render thoſe powers of attraction and repulſion, and thoſe phenomena of combination and ſaturation, which I muſt have recourſe to in treating of Light and Fire, familiar to my inquiſitive reader, by engaging him to exerciſe his thoughts on them. If he be not acquainted with the experiments made under the inſpection of the gentlemen to whom this eſſay is addreſſed, he may entertain ſome doubts concerning the fact ſtated in the latter part of the laſt queſtion: but on the tryal he will find it to be true; notwithſtanding the contrary aſſertion of the experimenter lately quoted, who, in treating of what he calls *alkaline air*, in p. 171. ſays, "Inflammable air admitted to alkaline air exhibited no particular appearance. "Water, as in the former experiment, abſorbed the alkaline air, and left the inflammable air as it was before. It was "remarkable, however, that the water "which was admitted to them became "whitiſh, and that this white cloud ſettled, "in the form of a white powder, to the "bottom of the veſſel."

And in p. 176. ſays, "Though alkaline "air be inflammable, it appeared, by the "following experiment, to be heavier than "the common inflammable air, as well as "to contract no union with it. Into a veſſel containing a quantity of inflammable "air, I put half as much alkaline air, and "then about the ſame quantity of acid air. "Theſe immediately formed a white cloud, "but it did not riſe within the ſpace that "was occupied by the inflammable air; ſo

“ that this latter had kept its place above
“ the alkaline air, and had not mixed with
“ it.”

After a very diligent attention to the phenomena of combination, which are exceedingly numerous, I have not obſerved one which is not conſiſtent with, and deducible from the ſimple powers of attraction and repulſion, which after a conciſe explanation, I have aſſumed as principles in treating of ſaturation. And from the ſketches I have given of this ſubject it appears, that there is no transformation of one kind of matter into another, when ſolid bodies form inviſible fluids, or when inviſible fluids form ſolid bodies; and that elaſtic fluids are not emitted from bodies by reaſon of a change of attractive powers into repulſive powers, when the parts are removed to a ſmall diſtance from each other; and that bodies may hold elaſtic fluids whilſt they are cold, which they cannot when they are heated: it moreover appears conſiſtent with the tenour of nature that the parts of Light ſhould repel each other, and attract ſome different kind of matter; and that Light ſhould be condenſed and ſaturated by other matter; and that theſe ſhould, nevertheleſs, form a compound, ſubtil, elaſtic, inviſible fluid, and a *tertium quid*, acting on bodies and acted on by them, in a manner different from that of the actions and paſſions of Light.

The uſes to be made of theſe obſervations, concerning the parts, properties, and appearances of homogeneal, compounded, groſs and ſubtil bodies, and the aſſiſtance which they afford us, in explaining the phenomena of Light and fire, will appear in the enſuing pages.

I formerly intended to add a ſection concerning the properties, by which compounds differ from the homogeneal bodies of which they are compoſed; and another ſection concerning the *vis inertiæ* of matter. But ſince this introduction is already extended to a great length; and ſince we may make a conſiderable progreſs in the Eſſay concerning Light, without attending cloſely to theſe ſubjects; I content myſelf for a while with what is ſaid of the firſt of them, in the ſixth ſection; and reſerve my thoughts on the *vis inertiæ*, to be introduced when I treat of the true motion of Light.

A PHILOSOPHICAL ESSAY CONCERNING LIGHT.

CHAP. I.

A Motion of Light is neceſſary towards Illumination and Viſion.

IN a room encompaſſed by opaque walls and floors, we have no viſual ſenſe of objects nor of Light; and we find that this darkneſs is either privation or quieſcence of Light. When a body in the act of combuſtion is brought into the room, we have viſual ſenſe of Light and of the objects in the room; and hence we learn, that not only the preſence of Light, but a motion of Light, is neceſſary towards illumination and viſion. For, if we ſuppoſe the Light to be emitted from the burning body, the velocity with which it ſpreads excentrically to every part of the room, from the burning body, denotes a rapid motion of the Light: but when we admit that no Light is projected from the burning body, then muſt we conclude, that the matter of Light exiſted previouſly in every menſurable part of the room, and during the utter darkneſs of it; and that ſince the quieſcence of Light is darkneſs, the motion of Light is the cauſe of illumination, and we can ſee objects only by Light in motion.

When the pyrophorus of *Homberg* is ſecluded from the immediate action of air, and is brought into the chamber; neither this pyrophorus nor any other object is viſible: but when the pyrophorus expoſed to air, enters into combuſtion, it is viſible, and illuminates other objects. And ſince the illumination continues whilſt phlogiſtic matter is emitted from the pyrophorus, and ceaſes when this emiſſion ceaſes, and when the reſiduary matter of the pyrophorus is dephlogiſticated or incombuſtible; it is evident that, if the Light ſeen, be projected from the ſubſtance of the pyrophorus, it is ſeen only during the rapid motion of it; and if the Light was not emitted from the pyrophorus, the illumination is owing to a motion which the circumambient Light receives from the phlogiſtic matter which is certainly emitted from the pyrophorus.

The phoſphorus of *Kunkel* cauſes no illumination, whilſt it is kept in the *Torricellian* void, and whilſt it is by any means prevented from emitting its phlogiſton. The ſame phoſphorus illuminates, more or leſs, as the quantity of phlogiſton which eſcapes from it, in a given time, is greater or leſs; and the illumination ceaſes when the phlogiſton is departed from the reſiduary incombuſtible ſaline matter, which with the freſh phlogiſton of any phlogiſtic body is capable of forming phoſphorus again. And ſince the phoſphorus is luminous only whilſt matter is manifeſtly moved from it; we clearly perceive that Light at reſt, whether in the phoſphorus or diffuſed in the chamber, is not ſenſible to us; and that the illumination cauſed by phoſphorus conſiſts in the motion of Light emitted from the phoſphorus, or in the motion which diffuſed and quieſcent Light receives from the moved phlogiſton of the phoſphorus.

The like obſervations may be made on the illumination cauſed by a flint ſpark, when particles of ſteel are burned; and on the ſtronger illuminations cauſed by the more rapid combuſtions of ſulphur, ſpirits, oils, bitumens, fuel, by the brilliant combuſtion of zinc; and may be reaſonably extended to the dazzling combuſtions in the ſun.

CHAP. II.

Light is not projected and moved with rapid progreſſive motion, from the Sun, or from burning Bodies.

OBSERVING the illumination cauſed by the ſun, by fires, and other bodies abovementioned; and conſidering that in all illuminated ſpace, Light is in motion; we muſt form one of theſe two concluſions: either the moved Light iſſues from the ſun or the burning bodies, and is projected thro' the whole of the illuminated ſpace, in immenſe quantity, to illuminate every menſurable part of that ſpace, as we ſee it does, and in cloſe ſucceſſion to produce the uninterrupted illumination which we perceive: or Light exiſts in every menſurable part of illuminated and illuminable ſpace; and the ſun and burning bodies only give impulſe or vibratory motion to the contiguous atoms of Light, and this impulſe or vibratory motion propagated in the circumambient Light, is the cauſe of illumination.

lumination. For we have no reaſon to imagine, that both the emiſſion and rapid progreſs of Light from burning bodies, and the vibration of Light already diffuſed in all ſpace, are neceſſary towards illumination or viſion; and it is repugnant to the rules of philoſophiſing to admit two cauſes of illumination, for every degree of which one of them will ſuffice. And of theſe concluſions, that which is inſufficient for the phenomena of Light, and unſupported by analogy, and repugnant to the known laws of nature, is falſe: and the other is the legitimate concluſion, and is not to be diſputed, until it is found inconſiſtent with the phenomena of Light, the laws of motion, and the tenour of nature.

As there is no defect of phlogiſtic matter, notwithſtanding the infinite number of combuſtions and other operations in which it has eſcaped from bodies and expanded, during many thouſands of years; and as we can trace the circulations of this matter emitted from burning bodies, until we find it combined in others, which in their turn become combuſtible; the powers by which the phlogiſtic atoms are drawn back to the earth, muſt prevent them from moving in ſtraight lines to any conſiderable diſtance from the burning or decompoſed bodies. So, if illumination were cauſed by the progreſſive motion of Light emitted from burning bodies, the Light muſt have been combined in the bodies; and in its progreſs from the bodies, it muſt be every inſtant deflected from the rectilinear courſe, by ſuch powers of attraction as cauſed the combination of it. But ſince we find that the courſe of illumination is rectilinear in any uniform medium, and is continued to diſtances unlimited and in all directions; it is highly improbable that Light forms a part of the ſubſtance of combuſtible bodies, or that it is emitted from them to cauſe the illumination.

The fluids which eſcape from bodies during the combuſtion or decompoſition of them, expand eccentrically from the bodies, by the repulſive powers of their parts. If Light be combined in bodies, we know no other cauſe of its emanation from them during their combuſtion, except repulſive powers of its parts, ſimilar to the foregoing repulſive powers; and Light flowing from bodies by ſuch powers, and with ſuch forces, would impel and move the bodies oppoſed in its courſe, and eſpecially thoſe bodies which reflect Light or are ſaid to ſtop Light in their pores; admitting that Light moving with its utmoſt velocity hath no momentum. But ſince the Light, which is moved where it illuminates, ſo that the illumination proceeds above 10,000,000 of miles in a minute, or above 800,000 times ſwifter than ſounds, is not found to impel the moſt opaque poiſed or light bodies, in the line of illumination; the theory of illumination by emitted Light is not reconcileable to the phenomena of Light, by any argument from the ſmallneſs of its parts, and from the ſmallneſs of their momentum; which ſubjects we ſhall ſpeak of in due time.

The quantity of tallow which burns from a candle of the ordinary ſize, in a ſecond of time, is not equal in bulk to the ſixth part of a drop of melted tallow. And the illumination cauſed by the combuſtion of this ſmall portion of tallow, may be ſeen even thro' air, in every part which the pupil meaſures of a ſpace of two or three thouſand ſquare miles. Reaſon revolts at the ſuppoſition that ſo much Light could be crowded in ſo ſmall a compaſs in cold tallow; we know no powers by which it can be projected, except thoſe of the mutual repulſions of its parts; we cannot from any analogy infer that ſuch a minute portion of groſs matter can concentrate and combine with ſo great a quantity of the repellent matter of Light; and unleſs we admit hypotheſis as a proof of this hypotheſis of the motion of Light, the ſuppoſitions of the ingenious Mr. *Canton*, Mr. *Melville*, and others, concerning the wide intervals between the parts of Light, relatively to the bulk of them, does not give any colour of truth to the notion of this emiſſion of Light from burning bodies.

If we ſuppoſe the moved Light, which illuminates in all ſpaces between the ſun and viſible bodies celeſtial and terreſtrial, to be projected from the ſubſtance of the ſun; and that it moves from the ſun to us in about eight minutes; all theſe ſpaces muſt be repleniſhed in the firſt eight minutes of ſunſhine, with as much Light as is ſufficient for ſtrong illumination, which is all that is at any time found equably diffuſed in theſe ſpaces; and every minute thereafter, Light will be concentrated or accumulated in them. But as Light can be concentrated by convex lenticular glaſſes and concave mirrors, beſides other means to be noticed hereafter; and as we are well aſſured that a concentration of Light to the thouſandth part of the ſpace in which it is uſually diffuſed, is capable of exciting great heat and combuſtion in bodies expoſed to it, wherever the ſun illuminates freely; the concentration of Light, reſulting from the preſumed continual emiſſion of it, muſt make the ſunſhine of every hour much hotter than that of the former hour; and in a certain time, from the firſt action of the ſun, which is to eight minutes, as the area of a burning glaſs is to the area of its real focus; this our world muſt be red hot and flaming: and the ſun muſt be waſting daily, and in time incapable of emitting Light or of illuminating our earth, by reaſon of the diſpendium of Light from every face of it, as well as from that preſented to us at any inſtant.

Theſe conſequences do not follow the action of the ſun, but are totally repugnant to our experience during thouſands of years; and the premiſes from which they flow are erroneous; however ingeniouſly the Rev. Dr. *Horſley* and others endeavour to extenuate the waſte of the ſun, which muſt be the conſequence of the ſuppoſed emiſſion of Light; unleſs the ſun hath a power of drawing back Light, as faſt as he is ſuppoſed to emit Light: for the falling of comets into the ſun, is a mere conjecture. And concerning that power, it were ſufficient to remark, that the exiſtence of it is not demonſtrated. But we may further obſerve, that it is altogether improbable. For the cauſe of illumination is not ſenſibly weaker in any one face of the ſun than in another; and the ſun acts inceſſantly in illuminating the ſpaces and bodies around it; and it is impoſſible, by any known property of matter or law of nature, for the ſame body to exert, at the ſame inſtant and in the ſame coaſt, a power of propelling any matter, and a contrary power of drawing back the ſame matter again, as quickly as it was propelled, and from the greateſt known diſtances : and it is impoſſible that two ſuch powers ſhould not counteract each other, and rather poiſe the matter on which they act, in a ſtate of relative reſt, than cauſe a rapid motion of it, progreſſive in ſome parts and retrograde in others interceding theſe. It is moreover to be conſidered, that if the Light ſuppoſed to be emitted from the ſun, were drawn back to the ſun as faſt as it is emitted, there could be no darkneſs in the night ; becauſe the current of Light returning to the ſun, muſt illuminate, as well as that proceeding from it, if illumination conſiſt in the progreſſive motion of Light.

Thoſe who imagine that the ſun emits the Light by which it illuminates, muſt allow that thouſands of ſtars, and of fires on this our earth, are continually emitting Light in addition to that of the ſun. And thus the error of the hypotheſis is aggravated ; ſince a multitude of bodies emitting Light inceſſantly into the ſame ſpaces, are not found to encreaſe the quantity of Light therein, nor to ſuffer any waſte of their ſubſtance.

The philoſophers who affirm that illumination is cauſed by a progreſſive motion of Light ; when they conſider how many ſuns, if the fixed ſtars be ſuns, and how many millions of fires, are continually emitting Light, by their hypotheſis ; and when they recollect that all maſſes of groſs matter are pervious to Light ; muſt acknowledge that all known places are repleniſhed with Light, and no place can be void of Light in any inſtant of time ; and our atmoſphere eſpecially, which is open to the ſun and ſtars and fires, can never be deficient of Light. And when they further obſerve how Light, condenſed in bodies placed in the focus of a burning-glaſs, expands from the bodies, when the inſtrument of condenſation is removed, nearly in the ſame manner as other elaſtic fluids expand when the condenſing power ceaſes ; they they will perceive, that by reaſon of

this

this expanſibility of Light, all places of which we have any knowledge muſt contain Light in quantities which are nearly as the ſpaces, except in the vicinity of bodies which attract or concentrate Light; as we ſhall ſhew hereafter. Now if the parts of Light by which we ſee the ſun, were emitted from the ſun, they muſt dart ſwiftly 800,000,000 of miles thro' a ſpace already ſupplied abundantly with Light, without impinging on the parts of it; and they muſt likewiſe move rapidly many leagues thro' the denſer parts of our atmoſphere, without claſhing with the groſſer atoms of air ſo as to be ſtopped by them; and when an ethereal fluid diffuſed in all known ſpace is aſſumed, they muſt moreover move thro' this ether without impediment, and with the foregoing velocity. But we have no experimental evidence of ſuch motion; it was originally ſuppoſed, only for the ſake of certain phenomena which may, in the preſent riper ſtate of natural knowledge, be explained without it, as we ſhall ſhew; and ſince there is no ſimilitude of it in nature, and it hath no conformity with the eſtabliſhed laws of motion, it is to common underſtanding incredible.

If the air were equally denſe at every altitude of the atmoſphere; and if the parts of air and Light, and of the ether if you will, were all diſpoſed ſo as to be equally diſtant from each other; it were poſſible that Light might move rapidly and progreſſively between theſe parts, in certain directions without touching them. But this cannot happen in all the directions in which we have ſenſe of rectilinear illumination: neither can it happen in air whoſe parts are unequally diſtant in any two different altitudes, and are perpetually changing their places and arrangement relatively to each other, when they are agitated by winds and other cauſes. And as we ſee againſt the wind, or athwart the wind, as well as with it, and thro' ſtill air in any one direction as well as in another, allowance being made for the turbid ſtate and greater denſity of the air near the earth; and thro' water and glaſs of any thickneſs, in which the motion of Light is not ſtifled by means to be conſidered hereafter, as well in one direction as in another; although the pores of theſe fluids, and eſpecially of incompreſſible ſolid bodies cannot be continued, in all poſſible directions, uninterrupted by the ſolid matter of the fluids and bodies, ſo as to give paſſage to the Light in a ſtraight courſe, however it may fall on them; Light is not moved from the ſun and burning bodies with a continued progreſſive rapid motion.

To explain how Light may paſs freely through ſolid bodies, ſome authors ſuppoſe that the pores of them may be much larger than their ſolid impenetrable parts; and the ingenious *Boſcovich* finding this inſufficient, ſuppoſes that matter is not impenetrable according to our conceptions of it. Such conjectures ill ſupport the hypotheſis, which they are intended to favour. Indeed they rather expoſe the weakneſs of it, by ſhewing the extremities to which men are driven, whilſt they attempt to maintain it.

Although it were admitted that the pores of the moſt incompreſſible and denſe bodies, ſuch as diamond or cryſtal, are an hundred times larger than the impenetrable parts of them, it is ſtill to be conſidered that theſe pores are not void of Light; and thoſe who contend for an ethereal fluid muſt admit that they are not void of ether: and the force of the foregoing argument is not abated, in conſequence of any conceſſion for the poroſity of bodies. But this will better appear on the following conſiderations.

If it were true that the parts of Light, which illuminate when we ſee a number of ſtars or candles, are emitted with great velocity from theſe bodies; theſe parts being moved in different directions towards each other, ought, either by impinging or by repelling each other when they approach, to be turned out of the rectilinear way between each luminary and the eye, and ought to take a courſe very different from that of the experienced illumination. According to the hypotheſis, the torrent of Light from the ſun is much denſer than that from a ſtar; and when the ſun ſhines obliquely on our horizon, the weaker torrent of Light flowing from the ſtars, ought to fall in with, or be turned out of its way by, the denſer and ſtronger torrent from the ſun; ſo that ſtars near the zenith ſhould be inviſible to a man looking towards them from the bottom of a deep pit. But theſe concluſions reſulting from the hypotheſis are falſe; and therefore the hypotheſis is erroneous.

When a convex lenticular glaſs fourteen inches in diameter and whoſe focal diſtance is fifteen inches, is placed parallel to the ſun's diſque, in a room cloſed on all ſides, except where the lens is placed at an aperture in the window; we ſee between the lens and the place of its focus, a figure diſtinctly defined by the Light which is ſuppoſed to paſs through the lens, and which is bent in its paſſage. This figure appears in conſequence of the reflections, made chiefly from particles of duſt floating in the air, and to an inattentive obſerver ſeems conical; the lens being the baſis, and the focus of light the vertex of the ſuppoſed cone. Now if the Light were projected from the ſun through the glaſs, and being bent in its courſe, at the ſurfaces of the glaſs, were impelled to the focal point; the parts of bodies placed between the center of the lens and the focal point, and near the focal point, ought all to be propelled from the lens, when they are moved by the incident Light. But we find that the bodies are expanded, and that their parts are moved, whilſt they are expanded and vaporated; and that theſe parts of the bodies, and of the ſmoak or vapours of them, move in as great quantity, and as briſkly againſt the ſuppoſed current of light as with it; and we therefore conclude that the Light which cauſes theſe effects hath not rapid progreſſive motion; although it certainly hath ſome other kind of motion, of which we are to ſpeak hereafter.

The phenomena of reflections of Light further ſhew, that illumination doth not conſiſt in a continued progreſſive motion of its parts. For a mirror placed in the ſun-beam admitted into a dark chamber, ſo as to reflect the illumination, in the line of incident illumination as nearly as is poſſible, does not weaken or ſcatter the illumination in the beam of Light; which it ought to do, if the incident and reflected Light were moved progreſſively in contrary directions: and the illumination obliquely incident on a broad mirror, is not found to diſturb the reflected illumination, as it ought, according to the laws of motion, if the Light of the incident and reflected beams which croſs each other, were moved rapidly and progreſſively; and as it ought, whether the parts of this Light impinge on each other, or ſhun each other by virtue of a repulſive power: and for the like reaſons the phenomena of illumination reflected regularly to a focus, by concave mirrors, in a direction oblique and contrary to that in which the Light is ſuppoſed to be moved from the ſun to the concave mirrors; plainly ſhew that Light is not moved in continued progreſſion.

But ſince the motion of Light muſt be progreſſive, if the ſun and burning bodies emit the Light when they illuminate; and ſince the motion of Light during illumination is not progreſſive; Light is not emitted by theſe. And this will better appear when we come to conſider the matter which eſcapes from burning bodies, and the manner in which it moves Light without propelling it, without being itſelf propelled to great diſtances from the bodies, and without any waſte of the ſubſtance of the planet which cauſes illumination, by the combuſtions on its ſurface; and it will ſtill better appear when we ſhew how other illuminations, by ſolar phoſphori and the electric fluid, may be effected, and how the phenomena may be explained, without our preſuming that Light is projected or moved in the manner deſcribed in the *Newtonian* ſchools.

If the parts of phlogiſton, when they eſcape from burning bodies, could occupy more ſpace when they are thrown aſunder than they do when they are combined in the bodies; or if theſe parts could abſolutely fill the ſpaces in which they are diffuſed, ſo as to exclude Light from them; the Light which is manifeſtly diffuſed around them, might receive progreſſive motion from them, analogous to the motion imparted to air by bodies which in expanding exclude air; or analogous to the motion imparted to a large body of water, when a ſtone is thrown into it: except that the motion of Light would be much ſwifter, for reaſons to be mentioned hereafter. But ſince Light exiſts in elaſtic fluids; and ſince bodies in expanding cannot exclude Light from the ſpaces which intercede their parts; it is not to be preſumed, that Light is propelled in this manner. And altho' the emitted matter of burning bodies may communicate motion to the parts of Light which lie in the line of their motion; this could not cauſe a progreſſive motion of Light to conſiderable diſtances, becauſe its parts are not coherent; and by the laws of motion, it could not cauſe rapid progreſſive rectilinear motion of Light, if Light were an elaſtic fluid; and by the ſame laws, it could not cauſe a progreſſive motion of Light continued to conſiderable diſtances, if Light were an inelaſtic rare fluid, without excluding Light from the vicinity of the burning bodies, contrary to our experience.

If we conſider the Light contained in illuminated ſpaces, we cannot from any analogy preſume that illumination is continued by any progreſſive motion of Light. When a ſtone is thrown into ſtagnant water, the motion of the parts of water contiguous to the ſtone, is communicated to the circumambient water; and the extreme circular waves which reach the banks, do not conſiſt of the parts firſt impelled, but of the water which was contiguous to the banks; and if the ſtone be ſmall relatively to the water, the motion of the water is manifeſtly undulatory, where it is not ſenſibly progreſſive. A perſon immerſed in water, can hear the colliſion of two ſtones in the water, at a great diſtance, as the learned Dr. *Franklin* obſerves. In this caſe the whole water hath no progreſſive motion, altho' motion is propagated in it to the greateſt diſtances at which the experiment has been made.

When we find motion thus excited in immenſe quantities of a groſs and heavy fluid, by forces incapable of giving ſenſible progreſſive motion to very ſmall portions of it; and when we conſider that the matter expanding from burning bodies doth not appear to have any conſiderable momentum ; we find ſome reaſon from analogy to preſume that the motion of Light is a propagated motion, but none to believe that Light is propelled freely thro' Light with progreſſive motion.

When a bell is rung, motion is ſenſibly propagated in air to the diſtance of many miles, without any continued progreſſive motion of the air ; and the force neceſſary to generate this motion is incomparably leſs than the force which would be neceſſary to propel ſuch a body of air through air with the velocity of ſound. Between our ſenſe of the vibrations of air, and our ſenſe of the motion of Light ; between ſtillneſs or quieſcence of air, and darkneſs or quieſcence of Light ; between ſound and illumination ; between the ſwiftneſs of ſound in a groſs and heavy fluid conſiderably denſe, and the greater ſwiftneſs of illumination in a rare fluid, whoſe parts do not gravitate ſenſibly ; between the force neceſſary to cauſe ſound, and the force neceſſary to cauſe illumination ;

we perceive ſome analogy. But we find none in elaſtic fluids to countenance the hypotheſis of the projection and rapid progreſſive motion of Light through Light, or the continued propulſion of one body of Light by another.

Air propelled from the bellows, or by the exploſion of gunpowder; and all other blaſts of air againſt air, cauſe eddies and devious motions of the air; and the projected air loſes its motion in the ambient air in a ſmall time and ſpace. So Light, if it be an elaſtic fluid as we ſhall preſently endeavour to ſhew, being projected from the luciferous parts of the ſun, or from the fire in a lighthouſe; would in a ſhort time and ſpace bend out of the right courſe of illumination and ſpend its motion in the circumjacent light.

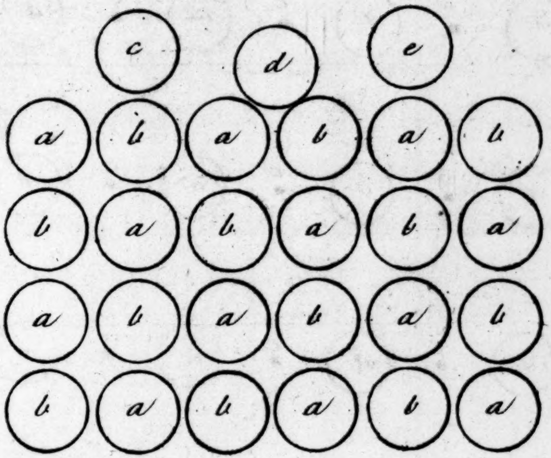
By how much the longer we look for ſimilitudes of the ſuppoſed emiſſion of Light and progreſſive motion of Light, by ſo much the more we find ourſelves diſappointed; and ſince this hypotheſis is repugnant to the phenomena already noticed, and may be found equally inconſiſtent with others that are to be mentioned hereafter; ſince it is incompatible with the laws of motion, and unſupported by any reaſon from analogy; we may conclude it is falſe: and this concluſion will be the more ſatisfactory as we proceed to explain the phenomena, and to relate the experiments which ſhew the powers by which Light is moved, and the kind of motion which it really receives.

The propoſitions in *Newton's Principia*, concerning the motion of fluids, and the arguments which perſuaded him to adopt the opinion that Light is projected and moved ſwiftly in progreſſion, will be conſidered in another place: But I muſt obſerve here, that *Huygens* and others who wrote before *Newton* entertained a different opinion; and that M. *Le Cat*, M. *Euler*, and many diſtinguiſhed modern philoſophers agree in rejecting this part of the *Newtonian* theory of Light; and that M. *Euler* eſpecially has lately made ſome advances towards explaining the phenomena, by motion propagated in a ſubtil medium.

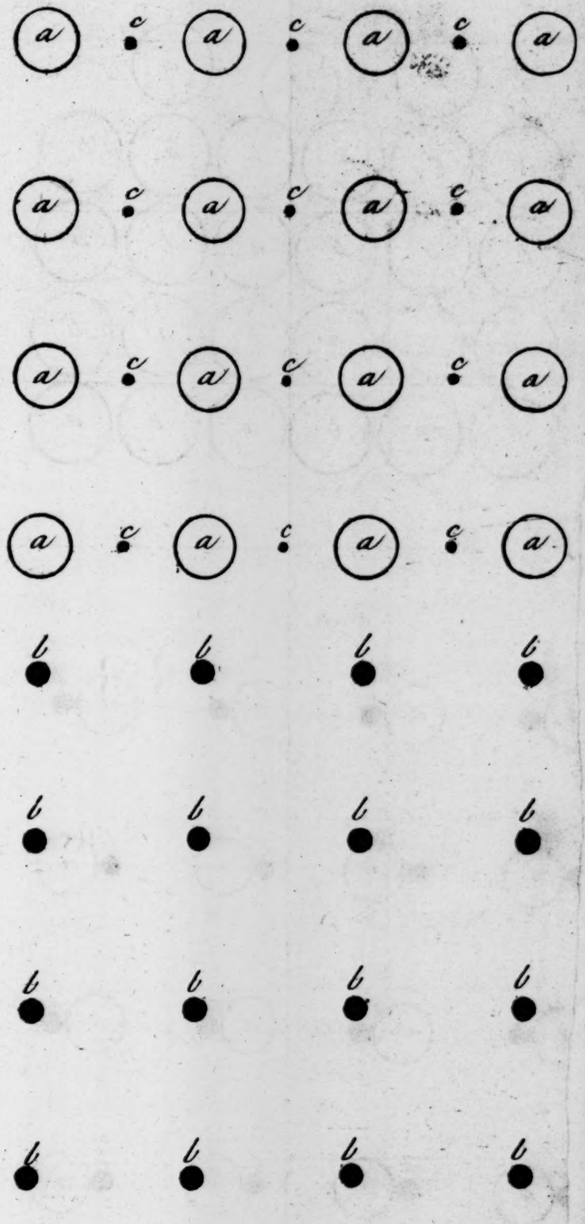
END OF THE FIRST VOLUME.

Pl. 1

Fig, 1



Fig, 2



Fig, 3